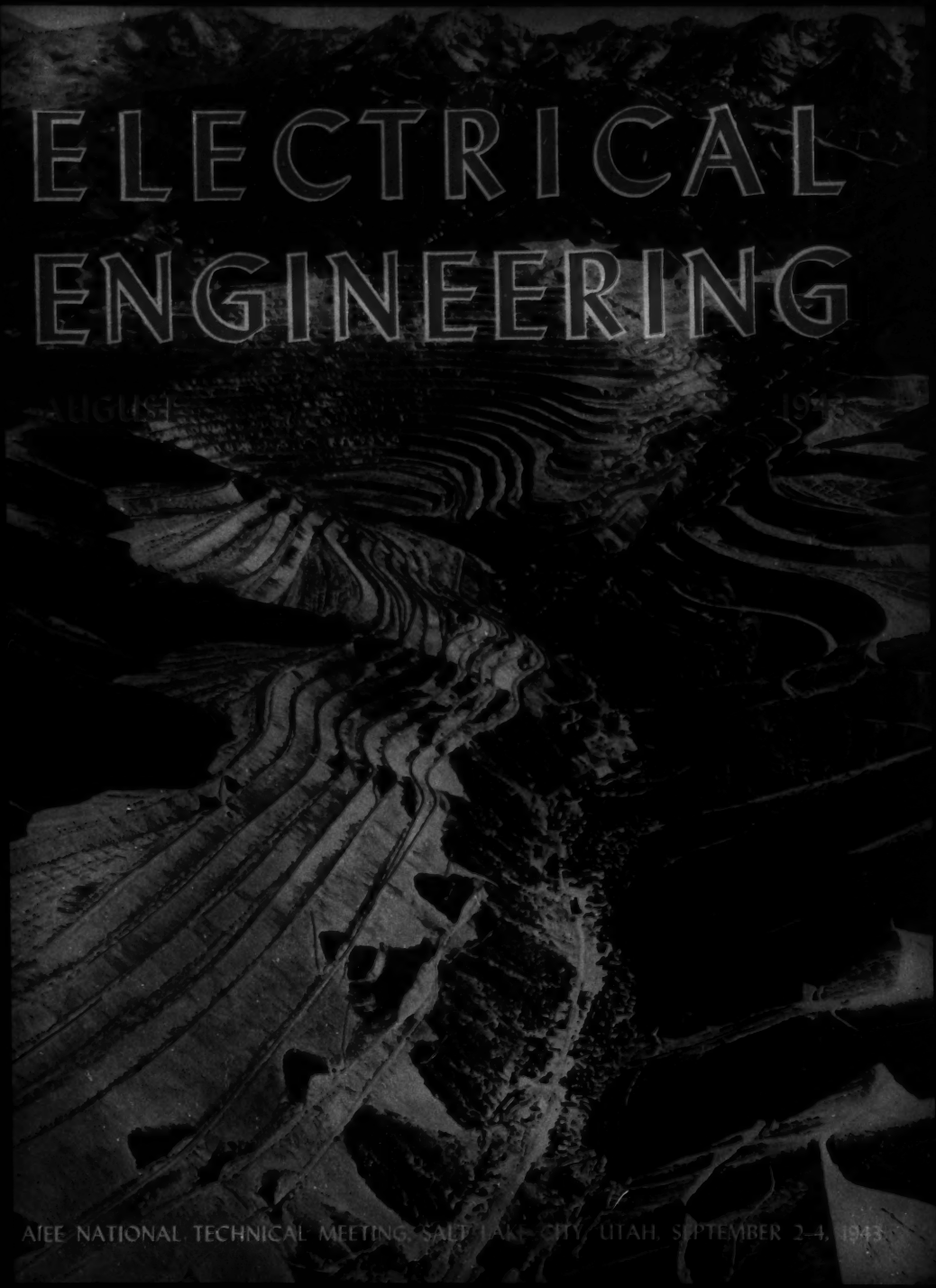
ELECTRICAL ENGINEERING



AUGUST 19

AIEE NATIONAL TECHNICAL MEETING, SALT LAKE CITY, UTAH, SEPTEMBER 2–4, 1943

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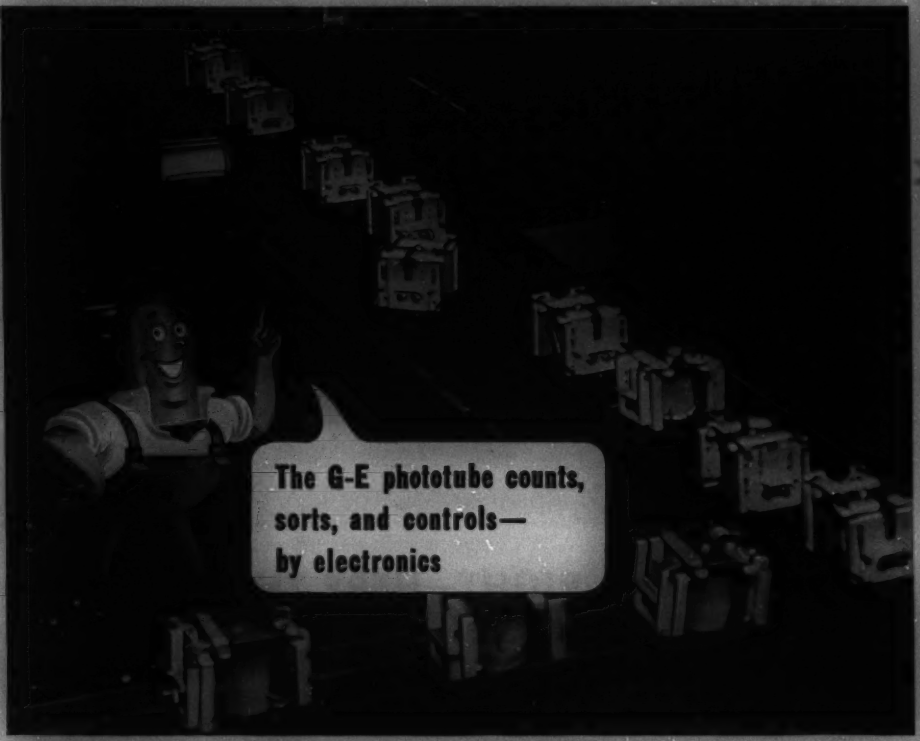

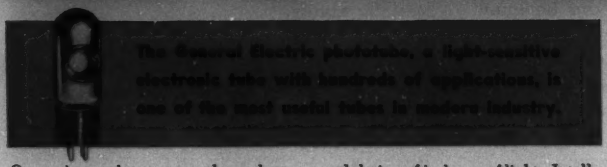

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Another rejects imperfect ball-bearings by automatically sizing each one to perfect dimensions. A third, responsive to radiant energy, controls temperature in an electric furnace.

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Free booklet on electronic tubes. Send us the names of interested men in your plant and we will keep them informed of electronic developments. For example, we will mail without charge an illustrated book entitled "How Electronic Tubes Work," written in easy and understandable language, and showing typical electronic tubes and applications. *Electronics Department, General Electric, Schenectady, N. Y.*

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HAZAPAK Rubberless Building Wire is approved by the Underwriters' Laboratories, Inc., under the provisions of Interim Amendments 44 and 69 of the National Electrical Code.

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Flame and moisture-resistant covering
Kodapak (cellulose-acetate butyrate) tape insulation
Bare copper conductor
Moisture-proof compacted kraft paper cushion
Listed and made to "DILSC" Specifications

There are two types of Hazapak Rubberless Wire, i.e.: Type EG (Emergency Grounded) and Type EI (Emergency Insulation).

Emergency Grounded Wire, Type EG, is the Underwriters' Laboratories designation for "wire of a type especially approved" in open wiring; in concealed knob and tube work; in non-metallic sheathed cable and as the grounded wire in any of the wiring systems covered by Articles 320 to 364 of the 1940 N.E.C. as provided in Interim Amendment 44. It is used as the white grounded conductor in assemblies such as Hazardex non-metallic sheathed cable and multiple-conductor lead-encased cables. Hazapak Rubberless Wire, Type EG, is always finished white and carries no surface markings. An attached tag indicates that it is to be used only on grounded circuits.

Emergency Insulation Wire, Type EI, as defined in Interim Amendment No. 69 of the 1940 N.E.C., may be used as the ungrounded conductor for non-metallic sheathed cable run exposed, or for open wiring on insulators, under the following conditions: 1. In dry locations only; 2. For voltages not exceeding 600; 3. If there are more than four conductors larger than No. 10 in an outlet or junction box, or in a cabinet or cutout box, the conductors must be individually wrapped with non-combustible, insulating tape. Type EI conductors should not be used in any hazardous location, except as provided for open work in Section 5075. In damp and wet locations, EI may be used with lead covering, Type EIL, in accordance with Section 3035. Type EI, as distinguished from Type EG, is surface marked and measured every two feet the same as rubber-insulated building wire. It is produced in standard building wire colors: black, red, green, yellow and blue. Underwriters' Laboratories approval labels marked "Type EI Building Wire" are attached to each coil or reel.

In the move to conserve rubber, the Civil Aeronautics Authority, Spec. 612, authorizes the use of wire such as Hazapak Rubberless for airport wiring, in ducts or for installation directly in the soil; the Federal Works Agency, Public Buildings Administration in its Suggested Specifications to Architects recommends the use of non-rubber insulated wire like Hazapak Rubberless under certain conditions; and specifications issued by office of Chief of Engineers, War Dept., Construction Div. for Theatre of Operations (Modified) and Mobilization Construction, Section 34 Interior Electrical Works, permit the use of Hazapak Rubberless Wire.

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CASE HISTORY No. 204

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PROBLEM: To find a permanently resilient, sulphur-free gasket for the cover of an oil-filled electric switch.

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Solution

When the manufacturer described this problem to Armstrong's sealing specialists, they recommended one of Armstrong's Cork-and-Synthetic-Rubber Compositions. Gaskets cut from this material met all of the requirements and have given trouble-free service for the past several years.

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A Slogan For All Americans

TYPICAL INSTALLATIONS

Typical Micromax Round-Chart Conductivity Recorder guarding the condensate return of a pulp mill. Calibration is in thousands of ohms.

Want to Immobilize This Leak?

To keep contaminated condensate from sneaking into a boiler's tubes and sabotaging its steam production, we can supply an instrument which will warn of the potential damage at its source until the maintenance crew closes the leak and thus ends the contamination. The method employed is to measure, continuously, the electrolytic conductivity of the condensate.

In the power industry's steam stations, conductivity is checked at each surface condenser, and after the pump, and at the drains of the stage heaters, by a multiple-point Micromax Strip-Chart Recorder. This instrument records the points, in rotation, at a rate of about a minute per point, on a chart approximately ten inches wide; the record may be in one color or in as many as six. The Micromax sounds an alarm or operates a signal light, as you prefer.

In many industrial power plants, where the condensate comes principally from the heaters for digesters, evaporators, cookers, etc., the preferred Micromax Recorder is apt to be a single-point instrument, normally connected to the main condensate return. When a leak shows, a dump valve opens to run the condensate to waste, while an operator switches the Recorder's connections, by hand, to the various lines which feed the header, until he has run down the leaking unit. The Recorder used may be either a Strip-Chart or a Round-Chart; the latter gives a narrower record but its indicating scale is readable from almost as far as it can be seen.

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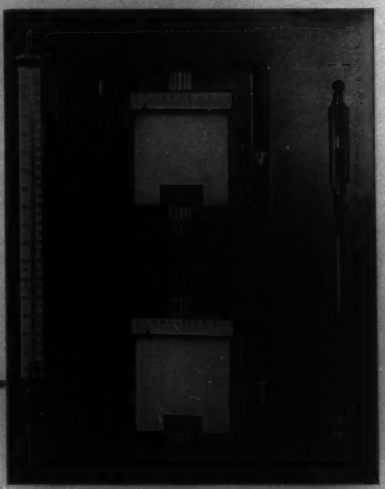
Jrl Ad N-95-163(4)



Typical Micromax Strip-Chart Conductivity Recorder on a central station's turbine board. It shows conductivity at hot well, or conductivity of condensed evaporator vapor, as manually selected. The upper instrument is a Micromax Temperature Recorder for steam, water and air temperatures; each is in a separate color.

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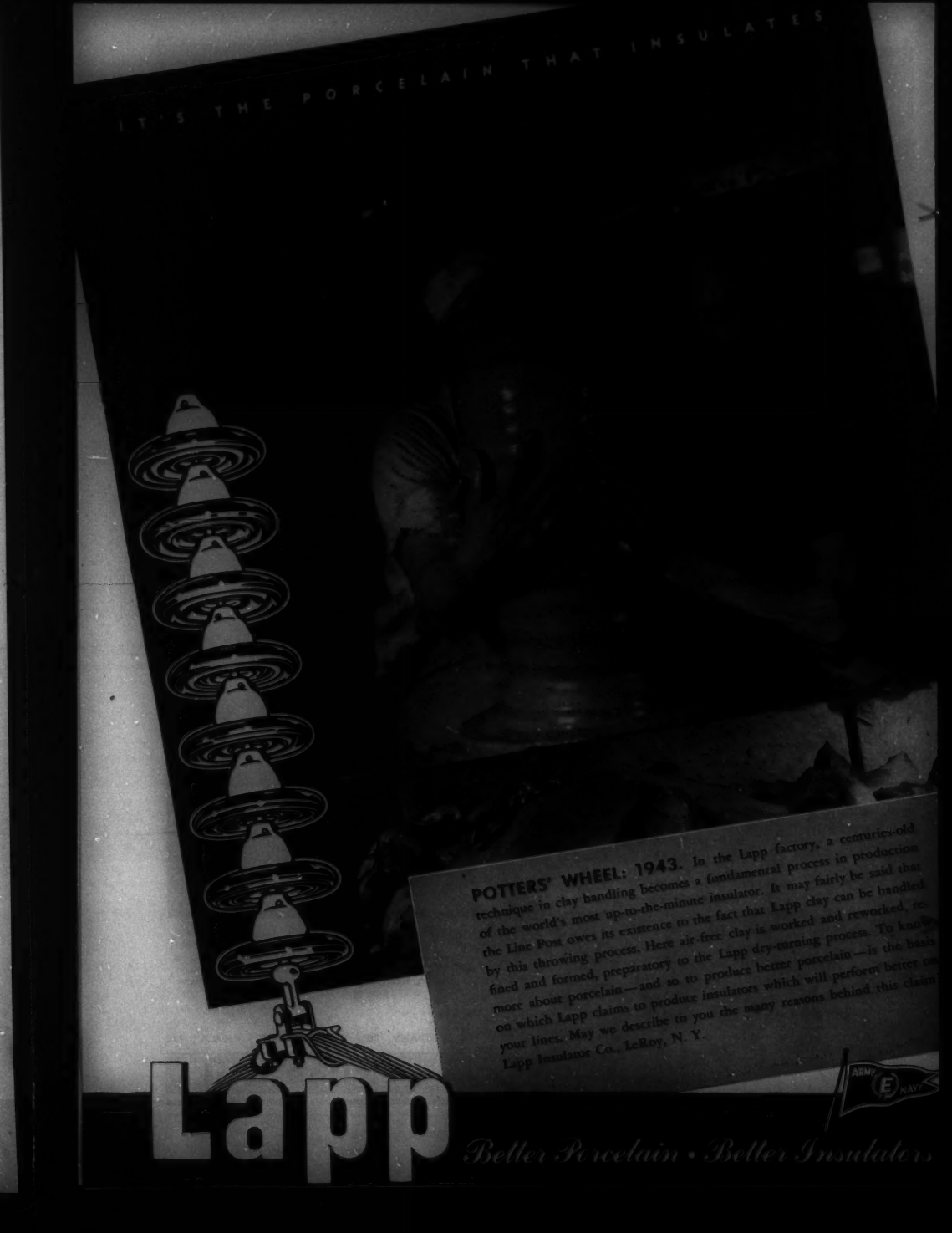
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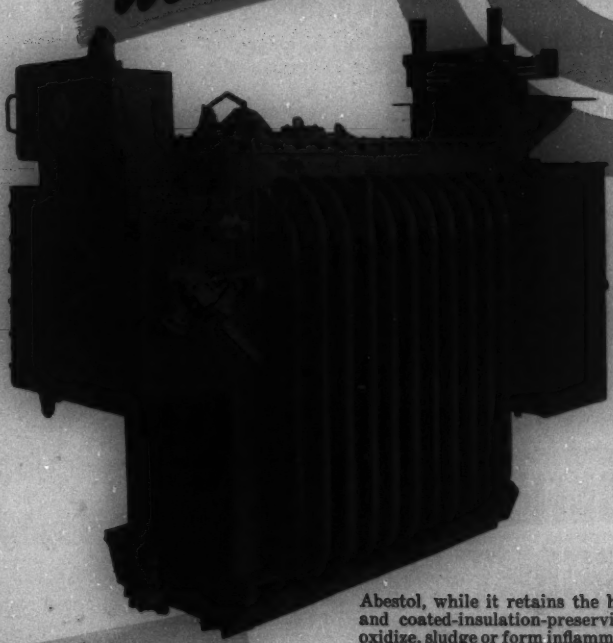
POTTERS' WHEEL: 1943. In the Lapp factory, a centuries-old technique in clay handling becomes a fundamental process in production of the world's most up-to-the-minute insulator. It may fairly be said that the Line-Post owes its existence to the fact that Lapp clay can be handled by this throwing process. Here air-free clay is worked and reworked, refined and formed, preparatory to the Lapp dry-turning process. To know more about porcelain—and so to produce better porcelain—is the basis on which Lapp claims to produce insulators which will perform better on your lines. May we describe to you the many reasons behind this claim? Lapp Insulator Co., LeRoy, N. Y.
ARMY E NAVY
Lapp
Better Porcelain • Better Insulators

THE TRIPLETT ELECTRICAL INSTRUMENT CO., BLUFFTON, OHIO
BACK UP YOUR BELIEF IN AMERICA...BUY WAR BONDS

Consider these advantages of ABESTOL TRANSFORMERS at load centers!



1 No vault necessary.

2 Substantial savings in secondary copper.

3 Reduced line loss.

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AMERTRAN

ELECTRICAL ENGINEERING

Registered United States Patent Office

AUGUST
1943

The Cover: This mine of the Utah Copper Company will be inspected in connection with the presentation of technical papers on mining and metallurgy at the forthcoming AIEE national technical meeting, to be held in Salt Lake City, Utah, September 2–4, 1943

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Planning for Things to Come

HAROLD S. OSBORNE
PRESIDENT AIEE 1942-43

Retiring President Osborne urges immediate planning to meet postwar engineering problems. The effective solution of these problems will require co-ordination with community and other planning. One problem of major importance is the greater unification of the engineering profession.

IT SEEMS CLEAR that at the close of this war we will find that many of the conditions of our life have been profoundly modified. Whatever it is that we are moving forward to, it will be in many respects quite different from the past. Under these conditions it is a sign that society is healthy if attention is directed to the future more than to the past. Rather than thinking of the postwar period in terms of a return to normalcy or to the "good old days," we shall do well to think in terms of planning for the new things to come.

Some may think that there is too much talk now about postwar planning. However, a great deal of thought will be necessary if we are to make suitable and adequate postwar plans. There is a great deal of groundwork to be done in advance if we are to have suitable plans available for action when the time for action comes in each of the many aspects of the postwar problems. If this discussion serves to stimulate constructive thought on the subject, it will be justified and time well spent.

OUR FIRST RESPONSIBILITY: THE PLAN FOR VICTORY

Let us first pause a moment in our thinking to do homage to the men in the fighting forces, who are now carrying out the one plan which it is absolutely essential shall succeed—the plan for victory. If that plan should not succeed we would have no occasion to make any other plans. In that tragic event the course of things to come would be determined for us, by the Axis dictators. Keeping this fact ever in mind should insure that we have the proper perspective. Our first responsibility is that of bringing the greatest possible effort to bear to help carry out the great plan of victory. For the duration this will remain our first responsibility. Whatever we do in postwar planning must not interfere with that.

ENGINEERING PLANNING: ONE PART OF THE BROAD POSTVICTORY PROBLEM

Planning for the postwar world covers the entire range of social problems and human activities. It involves, in many diverse fields, problems of great complexity and uncertainty in which the best efforts of man and of his social institutions will be necessary to obtain success or even to avoid catastrophe. For example, we must plan to maintain world peace—a necessity secondary in its urgency only to the plan for victory. That is the plan which we did not make successfully 25 years ago. There is planning for world reconstruction, and planning for the economic development of this country and of other countries. These matters are of great importance in shaping our future. We all have, as citizens and in other capacities, responsibilities in these matters which are fundamental. Mentioning these fields of planning merely by title is not to imply that we can dismiss them lightly. But, we cannot, in one discussion, consider all of the problems of the world. I propose that we direct our thoughts to some phases of planning for the future which are most directly related to our own engineering work and to the profession of engineering of which we form a part.

PLAN THE PLANNING

Each of us has a direct concern in the plans for the future of the organization in which his professional work is done. Many of us, whether associated with the educational, manufacturing, public utility, or other branch of the profession, are engaged to a greater or less degree in such planning. I would not undertake to indicate what the scope of that planning work should be in any specific organization. Indeed, it is my conviction that the proper scope of work is vastly different in the different organizations represented by our membership. There appear, however, to be general principles underlying this work.

At the start I believe we should plan the planning. Some of us may have received the impression, from some of the current talk about planning, that some work is possibly being done too soon. It is a fundamental of sound engineering that plans must be available for use at the time they are needed. But it is unavoidable in these days of rapid change that plans which are made before they are needed necessarily involve some waste effort. If we plan the planning we should thereby determine which planning jobs should come first, put first things first, and avoid the waste effort which might result from a less careful scheduling of planning.

We speak of this activity as postwar planning. That may be a misnomer. For the construction of plant or the manufacture of products, V-day is the day when materials and manpower become available for such purposes. For engineering education, V-day is the day

Essential substance of the presidential address delivered at the annual meeting during the AIEE national technical meeting, Cleveland, Ohio, June 21-25, 1943.

when students, out of uniform, again flock to the universities. These V-days may not be the same and may not be the time at which the peace treaty is signed.

BASIC REQUIREMENTS OF PLANNING

All the discussions of planning recognize the basic requirement that the postwar activities in the aggregate shall maintain a high level of employment and production. There are differences in the methods proposed to bring this about. This, you may recall, was the subject of Past President David C. Prince's presidential address[1] a year ago, and has been ably presented by him and others on various platforms during the past year, as representatives of the Committee on Economic Development.

Another basic requirement for many industries is that of re-establishing the practice of meeting the service requirements of our customers. This bulks large in the postwar planning of many utilities. For example, in the telephone industry we believe that if general business conditions are at least fair, this necessity will largely dominate our early postwar activities, since the construction of large amounts of plant will be necessary to give all the service demanded, including the locked-up demand of people who couldn't get service during the war, and to restore the quality of service which we like to give our customers in peacetime.

A general consideration in postwar planning is the resumption or establishment of programs of betterment. This also is important in the postwar thinking of utility engineers as large quantities of construction of new types of plant replacing older types, desirable for the improvement of service and for economies, have necessarily been postponed during the war.

The war experiences have developed a great deal which is new, and our planning must take account of the possible application of some of this in the postwar period. This, of course, applies pre-eminently in the applications of science to the development of new materials, new instrumentalities, and new technical processes. Its application is broader, however, than material things. It includes experience in getting along under difficult conditions, in doing the best with what we have, in meeting heavy overloads, in cutting out some of the frills in our products or services and finding out how to get along in the best possible way without them. All of this totals up to a grist of experiences of which we must take advantage, each in his own field, if we do a thoroughgoing job of postwar planning.

To plan effectively for the future we must recognize also that continuing rapid change will probably be a characteristic of the era in which we live. This recognition appears repeatedly in the current discussions of planning. For example, it seems to be the keynote of an analysis of the postwar problems of the engineering colleges presented by Doctor William E. Wickenden last October to a group of administrators of engineering colleges and universities.[2] In his inimitable language, Doctor Wickenden points out that after the war we shall face a radically altered social and economic structure in which this country will have irrevocably assumed world responsibilities. Technical education, broadly defined, will become the main stem of American higher education, he believes, and as such will have to carry a much larger share than heretofore of the cultural responsibility of American life. To meet their responsibilities, educational institutions will have to shed many ideas of the past. For example, there may be increased emphasis on differentiating undergraduate work along the lines of research and development, construction and operation, and management and business relations, with reduced emphasis on the classical divisions of engineering into technical branches—civil, mechanical, electrical, and so on. These comments of Doctor Wickenden illustrate for education a need that holds in all branches of the profession.

These basic considerations suggest a breadth in the scope of postwar planning which has not always been reflected in the discussions on this subject. Adequate postwar planning involves not only drawing blueprints of the shape of things to come, perhaps under a variety of assumed conditions; it involves, also, preparing ourselves to handle effectively the volume of work and the new problems which will come upon us at that time.

For example, I have mentioned that the postwar plans for the telephone industry indicate the construction of large amounts of plant. It may be too early now to draw up detailed plans for the specific projects of that program. However, to carry out that program effectively, a large amount of preparatory work should be done in advance. This includes general fundamental engineering plans taking into account the probable developments in demand for service and the availability of new instrumentalities; a critical study of past and current engineering practices to see whether the experience of carrying heavy service overloads during wartime may not suggest some modifications in practice which can be carried forward advantageously into the postwar period; the training of engineering and other personnel in new techniques; getting into good shape any additional records required for the effective conduct of the postwar program; and a careful consideration of the long-term effect of underlying trends and of new possibilities for service brought about by developments in service demands and by new instrumentalities.

I mention the telephone merely because of my familiarity with telephone problems. This approach, seems to me to be illustrative of a general principle. If we think of postwar planning broadly, there is much preparatory work to be done before we get to the blueprint stage, and much of this comes in the class of first things to be done first.

COMMUNITY PLANNING

When one engages in postwar planning for his own organization, it comes to his attention forcibly and re-

peatedly that his planning is dependent in part on the planning of others. This reaction of planning in the broader fields applies in greater or less degree to almost the entire range of postwar planning activities. Though it is not feasible to discuss this large field now, it seems desirable, nevertheless, to consider the relation between planning for our own organizations and planning for the next larger social unit—the community.

The fact is that the organizations for which we are planning are in each case a part of a community and our futures are tied up inextricably with the futures of the communities as a whole. Perhaps the most extreme case of this interdependence is the public utility. Such a utility, whether power, gas, or communication, is giving service to a community. Its property consists almost wholly of fixed plant located not only in the community but in specific localities throughout the community. Anything which tends to increase the development of the community, anything which modifies the distribution of people throughout the community, anything which tends to prevent wasteful and unsuccessful attempts at the development of localities or which stabilizes conditions in existing neighborhoods, is of most direct concern to it. Other industries, although representing a less extreme case, are in a somewhat similar position. Every industry has a direct stake in the development of the community because of its effect upon the ability of workers to obtain satisfactory and economical living conditions and on the ease of doing business, and because of the impact of the cost of community government.

In the early stages of the development of American communities it was customary to take for granted the continued rapid expansion and the prosperity of communities, particularly of metropolitan areas. This faith was to a large extent justified. Now, however, with a tendency for the total population of the country to stabilize, and with many influences tending to shift industry and to accelerate the migration of populations, we can no longer take for granted such continued expansion and prosperity of all communities. For example, Doctor Philip Hauser, assistant director of the Census, has published recently an interesting analysis and prophecy regarding the future of 135 metropolitan areas in the United States.[3] He prophesies that about 40 per cent of these will probably retain an above-average wartime growth; that about 30 per cent will lose population, or at best become stabilized; and that the other 30 per cent are in intermediate situations more difficult to analyze. The fact that at least one expert has reached such conclusions illustrates the importance of present trends in community planning.

Community planning dealt first with the future expansion of communities into undeveloped areas, including, in some notable cases, the laying out of entirely new cities. As our communities have grown older, increasing importance has been attached to stabilizing conditions and to the rehabilitation of such of the older parts of the community as have become blighted. Then came the war, with a devastating effect in accelerating changes of industry and the relocation of populations to a degree which normally would have taken many years to bring about. In the haste of war preparations some good planning work was done in the locating of industries and housing developments, and much was done with poor planning or none at all.

We look forward now to a postwar period which will be second only to the early war period in the intensity and extent of shifts of industries and populations as conversion is made from war production to peace production. How will these changes affect the individual community? What will be the industrial activity of the community and what population will be supported by it? What would be the physical development of a community to provide best for this population and for the industries and businesses with which they will be associated? These questions are in the forefront of community planning problems today.

In my judgment community planning, generally speaking, has been only partially successful in the past. This has been due largely to lack of popular support, arising from a lack of appreciation on the part of those most directly concerned of the importance of this subject to them in their own future planning. If we are to have an adequate quantity and quality of community planning there must be a general understanding of its importance.

An important part of community-planning activities is usually focused in an official planning agency associated with the local government, designated as a city planning commission or a regional planning commission. However, such an official planning agency is only one of the groups which should interest themselves in community planning if it is to be fully effective. The co-operation of every citizen is necessary both for making adequate plans and for carrying them out. Many questions important in community planning, including those related to the future industrial development of the community, are beyond the power of the local government to answer. The carrying out of such plans is dependent on the activity of many groups concerned both inside and outside of the community government. The citizens must accept the plans which are best for the community as a whole.

For these reasons it seems clear that adequate community planning requires not only an official planning commission but also the sustained interest and action of groups of citizens acting through their various organizations. Such organizations may include Chambers of Commerce, service clubs, various civic organizations, and neighborhood organizations of property owners. Above all I should like to see the engineering groups in every community take the lead in establishing organizations of citizens who will concern themselves directly in planning the future of their communities.

GREATER UNIFICATION OF THE ENGINEERING PROFESSION

It is obvious that participation by engineers in the planning of a community can be done best if all the engineers of the community work together as a united group rather than as a number of separate engineering groups. In going about the country during the past year visiting Sections of the AIEE, I have been impressed by the close co-operation in many localities between engineers of all categories, including the sections of the great engineering societies and other groups. I have a list of about 75 local and regional societies and clubs which are endeavoring to bring about in their localities a co-ordinated activity of all engineers. These organizations are increasing in number and growing in effectiveness. They take an active part in community affairs, and represent engineers as a whole before the people.

Frequently, in my visits to Institute Sections, the Section officers have asked how soon the national engineering organizations will get together in a similar way. I believe this question, more often than any other, is in the minds of our members as they think of plans for the future of our own organization.

Let us review briefly what the situation is with reference to the organization of engineers in this country. I think we can say without boasting that the great technical engineering societies have done and are doing a magnificent job. The four founder societies together have a membership of about 67,000 (not excluding duplications) and are still the largest engineering societies in the country among the dozens which have been organized. Add to these about half a dozen other large technical engineering societies and there is a total membership of about 100,000, a membership which has grown steadily through the years except during the depth of the depression.

The national organizations of these societies are devoted largely to technical and educational work. Their members are the backbone of the 75 local and regional engineering organizations, and through these organizations do a great deal of civic and community work.

The national engineering societies are co-operating directly and informally on many questions and also through a number of co-operative organizations. The United Engineering Trustees, on behalf of the four founder societies, owns and operates the engineering building in New York, maintains an engineering library, and administers for the advancement of research the funds of the Engineering Foundation. The Engineers' Council for Professional Development, a relatively new organization, has a fine record of progress toward its objective of higher professional standards of education and practice, including able work in the field of selection and training of engineers, and in the certification of courses of instruction in engineering colleges. In that organization eight national engineering societies co-operate. There is a joint conference of the presidents and secretaries of five of the engineering societies. There are several joint boards of award, each representing four or five national engineering societies. The American Standards Association was launched by the united efforts of five engineering societies and has now grown to such a stature that the professional societies have a minority although still a very important voice in the conduct of its affairs.

In view of this splendid record of accomplishment and co-operation, some may ask whether anything is lacking in the organization of the engineering societies. An answer to this question, and one which I believe represents the opinion of a majority of engineers, is that the engineering profession needs, and also the country needs, a central agency which can represent the entire engineering profession in matters of public concern. This point of view has been ably expressed by previous presidents of the Institute and by numerous distinguished engineers speaking before this Institute and other engineering societies.

On the one hand there is a fading of the boundaries that once separated more definitely than now the civil, mechanical, mining, and electrical engineering fields. The application of fundamental scientific knowledge and the growth of arts based on engineering are to an increasing extent breaking across these boundaries. A large number of the men in the top grades of membership in the founder societies need no longer be considered mechanical engineers, civil engineers, or electrical engineers. They are *engineers*, the scope of whose responsibilities cuts across the boundaries of these classifications.

Furthermore, public and semipublic questions involve important engineering considerations to an increasing extent—considerations which also cut across the boundaries of these classifications. There is a need for united consideration by the engineering profession as a whole of many questions, particularly in giving advice to the numerous agencies of government on the engineering phases of public questions.

The four founder societies had for a number of years an organization intended to fill this need at least in part—the American Engineering Council. Associated with the founder societies in this project were a number of local and regional organizations. The American Engineering Council was discontinued at the end of 1940. I believe that the reasons why the Council was not wholly successful are technical and organizational in character rather than related to the fundamental soundness of the purposes of the organization.

The professions of medicine and law, as has been said often and well, are far ahead of the engineers in respect to organization. The American Medical Association and the American Bar Association, representing smaller groups than the engineers, are effective media through which the special knowledge of medical men and lawyers is brought to bear on public questions.

But great public engineering works are constructed in this country and the group opinion of the body of engineers is not even expressed.

At least two attempts, not backed by the founder societies, have been made to build up engineering organizations which would do work for the benefit of engineers of all technical classifications. The American Association of Engineers was chartered in 1915 "to promote the social and economic welfare of the engineer, to stimulate public service in the profession, and to encourage and develop the efficiency of the engineer." It expected to enroll 100,000 members. Its membership rose by 1921 to 28,000. Its present membership is 5,000. More recently, in 1934, the National Society of Professional Engineers was organized with somewhat similar objectives. Membership in this society is open to all engineers registered under the laws in their respective states. This society has a membership at the present time of about 8,000.

Both of these organizations have criticized the technical engineering societies. We have not, it is said, measured up to our opportunities in the advancement and service of the profession. We exhibit "smug complacence in a circumscribed sphere of self-aggrandizement and, above all, failure to manifest concern for and participate in the affairs of community, state and nation as organized units of society." We represent an old order which is passing.

I think we should take these criticisms with a grain of salt but also in a sober spirit of reflection and self-examination. We not only have criticism from those outside, but also many inside the societies feel that the engineering profession is not organized to take the part in public affairs which it should. There is also the feeling of many that engineering is not recognized as a profession as fully as it should be. People still speak of the three learned professions, divinity, law, and medicine. One must look far in the unabridged dictionaries to find engineering among the examples which are given of professions. These criticisms seem to me all to be related.

I believe that the great national engineering societies have an important social responsibility, both to their profession and to their country, to plan what is the best form of organization of the engineering profession. The joint conference committee, consisting of the presidents and secretaries of five national engineering societies, voted at its last meeting to invite the constituent societies each to appoint members to a joint committee for the study of the problem and the presentation of recommendations as to the most desirable form of organization.

I hope this committee will be appointed and will recognize their assignment as a planning job which is not only important but difficult. It has been the subject of much study in the past and, apparently, we have not come to the right answer. Eleven years ago this question was studied by a joint committee of the four founder societies. That committee agreed that a central administrative agency should be set up which should eventually supervise as many joint activities of the societies as feasible. But the committee was unable to propose a form of organization which would find general acceptance. The complication of the problem is well brought out by an interesting report made in 1941 by a committee of the Cincinnati Section of this Institute which pointed out that the problem as a whole involves three groups of engineering societies—the great national societies devoted primarily to technical work, engineering organizations concerned primarily with the education, legal qualification, and professional development of the engineer, and the local and regional engineering societies.

Basic to any proposal for the establishment of a central co-ordinating or administrative agency is the purpose to be achieved by such central organization. It seems to me there may be many purposes. Surely, the area in which co-operative action between the present engineering organizations may be beneficial is not wholly covered by the activities of our present co-operative enterprises. There are a number of cases, in this country and in other countries, of collaboration between scientific societies or engineering societies as evidence.

While many purposes may be served by a centralized agency for the engineering profession, it is my view that the plans should be built about a central purpose which is professional in character. Many organizations are directed primarily to the service of their members. These fill a necessary and useful purpose but their aim is not necessarily a professional aim. The term "profession" implies a stewardship. The thing which distinguishes a professional man, as Doctor Bush has said so well,[4] is his use of special knowledge for ministry to the people. While engineers come from many specialized branches of the main stem of engineering knowledge and represent groups whose interests are by no means identical, they find professional unity through such ministry. I believe that failure fully to recognize this fact has been an important reason for the imperfect success of past organizations which have attempted to represent the engineering profession as a whole.

In making our plans for the future of the engineering profession, let us aim for a unity which will make possible the highest form of professional expression. It is through emphasis on ministry to the people rather than on direct service to its members that such an engineering organization may achieve the highest professional standing. And in doing this it will indirectly help all engineers through the increased appreciation on the part of everyone of the greatness of the engineering profession.

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Ultrashort Electromagnetic Waves

V—Radiation (Continued)

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This article is the concluding portion of the fifth lecture in the series on ultrashort waves sponsored by the basic science group of the AIEE New York Section. In the design of radiators or antennas for ultrashort waves a complete solution of Maxwell's field equations usually is not practicable, and engineering approximations are resorted to. The first installment (July issue) presented a method to be used when the distribution of current and charge over the radiator surface is known. This concluding portion presents a second method for the calculation of the field in space on the basis of known field distribution in the immediate vicinity of the radiator.

IN the first half of this article a method was developed which is used to calculate the radiation fields of radiators with a known current distribution. This method could be used to calculate the radiation fields of such radiators as an electromagnetic horn or a metal box with an aperture if the current distribution along the inner and outer surfaces of such a radiator were known. Usually such application of method 1 is at least very inconvenient. To convince ourselves of this fact we need only contemplate the integration over the inner surface of a metal box with an aperture. The difficulty is not so much that the integrals are apt to become unmanageable as that the current distribution may not be known with adequate accuracy. For example, in the case of the metal box with the aperture, the current distribution inside the box may be completely unknown, and the only quantity which could be measured with reasonable ease is the electric field in the immediate vicinity of the opening.

METHOD 2

It would be very convenient if from such relatively meager knowledge it were possible to calculate the components of H and E at all other points in space. It happens that this may be done with some limitation with the aid of the so-called *equivalence principle* together with method 1.

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In order to explain the equivalence principle, it will be convenient to focus our attention on the radiator of Figure 12. This is a typical problem, and we are not in danger of deriving results applicable to just one particular case. Let us begin by assuming that both H and E are known at every point along the aperture which we shall call surface S. The problem is to calculate H and E at a point $P(x, y, z)$ in the surrounding space. We may start by asking ourselves the following question: Is it possible to devise a distribution of currents and charges, the field of which would cancel precisely the actual field? For, if this were possible, we could use method 1 to calculate H and E produced by the distribution of currents and charges, and the values of H and E found in this manner would be exactly equal to the actual field except for a reversal in sign.

The problem of devising such a current and charge distribution has more than one solution. Any one of these possible solutions would serve our purpose, provided, of course, that the expressions for current and charge density in terms of H and E are relatively simple. This current and charge distribution need not be physically realizable. On the contrary, it may be as impracticable as we wish, as long as we are able to calculate the field which it produces, and the field is equal and opposite to the actual field. Since a volume distribution of current is much more complicated than a very thin current sheet, we shall attempt to construct a current sheet.

Let the surface of the current sheet be surface S which closes the aperture of the wave guide in Figure 12. Let i be current density per unit length measured at right angles to the lines of flow. Let σ be the electric-charge density per unit of area of surface S, and let E and H be the actual undisturbed electric and magnetic fields along surface S. The values of E and H will be assumed to be known at every point along surface S.

It will be convenient to resolve H into two components H_n and H_p. H_n is normal to S and H_p is parallel to S. The direction of H_p will be such that H_p, H_n and H all lie in the same plane, which is normal to S. The electric field E will also be resolved into similar normal and parallel components, E_n and E_p.

Let us direct our attention to a small portion of surface S. Such an element of S is shown in Figure 13. In this figure, dotted line AB is drawn parallel to H_p.

Points C and D on line AB are any two points separated by a very short distance l. Let a current of surface density $\boldsymbol{i}$ flow across line AB, and let the direction of the lines of flow between points C and D be perpendicular to CD. The total current which flows across CD is then il. This current will produce a magnetic

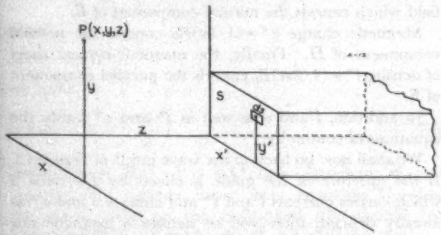


Figure 12. Radiating end of a rectangular wave guide

field which, in the immediate vicinity of surface S, will be parallel to the surface. Figure 14 shows the state of affairs in the plane which passes through line AB and which is perpendicular to surface S. This plane would be at right angles to the paper in Figure 13, and its trace is line AB. In Figure 14 the current is flowing toward the reader. The contour $abcd$ indicates a typical line of force of magnetic field $\boldsymbol{h}$ of current il. If we take a unit magnetic charge around the contour $abcd$, we shall do work which approaches $2l \cdot h$ when distances cb and ad are made very small. This same work must be equal to $4\pi/c$ times the current. It follows that

$$2hl = \frac{4\pi}{c}(il), \qquad h = \frac{2\pi}{c} i \tag{66}$$

From this it is clear that, if we make the magnitude of current density $i = (c/2\pi)H_p$, and the direction of $\boldsymbol{i}$ perpendicular to H_p at every point along S, the magnetic field produced by such current sheet will be $+H_p$ on one side of surface S and $-H_p$ on the other side of S. This current sheet would cancel completely the H_p component of $\boldsymbol{H}$ on one side of S.

Since, in general, H_p is not constant over surface S, the value of $\boldsymbol{i}$ will also vary from point to point. The value of $\boldsymbol{i}$ will vary even in the direction of the lines of

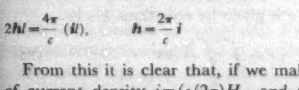


Figure 13. Lines of current flow

flow. For example, the current density along $C'D'$ may be greater than along CD, even when the direction of $\boldsymbol{i}$ and therefore of the lines of flow remains the same, that is, even when the lines of flow neither converge nor diverge. In a physically realizable system this could happen only if there were a variable surface charge density σ related to the current by the equation of continuity

$$\frac{\partial i_x}{\partial x} + \frac{\partial i_y}{\partial y} + \frac{\partial \sigma}{\partial t} = 0 \tag{67}$$

If we choose the co-ordinates so that x is parallel to the lines of flow, then $\partial i_y/\partial y = 0$, $i_x = i$ and $(\partial i/\partial x) + (\partial \sigma/\partial t) = 0$. If our current distribution is to behave in accordance with the continuity equation, we must have σ which is very closely related to H_p. Since $i = (c/2\pi)H_p$ we have

$$\frac{c}{2\pi}\frac{\partial H_p}{\partial x} + \frac{\partial \sigma}{\partial t} = 0 \tag{68}$$

Surface density σ is always accompanied by an electric field e which is normal to the surface. The magnitude of this normal field is $e = 2\pi\sigma$. Half of the lines of this electric field terminate on one side of the surface, and the remaining half on the other side of the surface.

If we substitute $e = 2\pi\sigma$ into equation 68, we find that

$$\frac{\partial H_p}{\partial x} = -\frac{1}{c}\frac{\partial e}{\partial t} \tag{69}$$

In an electromagnetic field, $\boldsymbol{H}$ and $\boldsymbol{E}$ are not independent but are such that

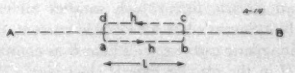
$$\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y} = \frac{1}{c}\frac{\partial E_z}{\partial t}, \text{ and so forth}$$

If the co-ordinates are such that x, as before, is along the lines of flow of $\boldsymbol{i}$, z is perpendicular to S, and y is in the direction of positive H_p then $E_z = E_n$ and

$$\frac{\partial H_p}{\partial x} = \frac{1}{c}\frac{\partial E_n}{\partial t} \tag{70}$$

By comparing equations 70 and 69, we see that $e = -E_n$ except for a term which is independent of time and which

Figure 14. Magnetic field of current in Figure 13



can be put equal to zero without further worry when we are interested in alternating fields. The sign of e depends on the direction of $\boldsymbol{i}$. When $\boldsymbol{i}$ is in the direction of positive x, $\partial i/\partial x$ is positive, σ is negative, and $\boldsymbol{h}$ is negative on the positive z side of S. On this same side of S, field e is also negative. It follows that, when the direction of $\boldsymbol{i}$ is such that its magnetic field $\boldsymbol{h}$ cancels H_p, the charge density accompanying $\boldsymbol{i}$ produces electric field e which cancels E_n on the same side of S.

So far, we have accomplished only about one half of what we set out to do. Our object was to devise a distribution of currents which would cancel all components of the actual field. We have obtained a distribution of electric-current density $\boldsymbol{i}$ and of the accompanying electric-charge density σ which cancel H_p and E_n in the immediate vicinity and on one side of surface S. H_n and E_p still remain. It is clearly necessary to superimpose on surface S something in addition to $\boldsymbol{i}$ and σ to take

care of H_n and E_p. H_n can terminate only on magnetic poles. We have no choice: we must add magnetic-surface density $\sigma^* = (1/2\pi)H_n$. This magnetic-charge density, like H_n, is a function of time, and $\partial\sigma^*/\partial t \neq 0$. If the magnetic charges are to be confined to surface S, and their sum total is to remain invariant, that is, if these charges are not to disappear and reappear, there must be a "magnetic current" of density i^* which is related to σ^* by the equation of continuity

$$\frac{\partial i_x^*}{\partial x} + \frac{\partial i_y^*}{\partial y} + \frac{\partial \sigma^*}{\partial t} = 0 \tag{71}$$

If the direction of x coincides with that of i^*, then $i_x^* = i^*$, $i_y = 0$ and

$$\frac{\partial i^*}{\partial x} + \frac{\partial \sigma^*}{\partial t} = 0$$

but since $\sigma^* = (1/2\pi)H_n$,

$$\frac{\partial i^*}{\partial x} + \frac{1}{2\pi}\frac{\partial H_n}{\partial t} = 0 \tag{72}$$

We may compare this equation with the general relation *a* between E and H which, in rectangular co-ordinates, is

$$\frac{\partial E_y}{\partial x} - \frac{\partial E_x}{\partial y} = -\frac{1}{c}\frac{\partial H_z}{\partial t}, \text{ and so forth} \tag{a}$$

If the direction of y is parallel to E_p, and z is perpendicular to S, $E_z = 0$, $E_y = E_p$, and $H_z = H_n$. Hence

$$\frac{\partial E_p}{\partial x} = -\frac{1}{c}\frac{\partial H_n}{\partial t} \tag{73}$$

Equations 73 and 72 become identical if $cE_p = 2\pi i^*$, and i^* is perpendicular to E_p so that the directions of x in equations 73 and 72 coincide.

We shall assume that the magnetic current produces an electric field which satisfies an exact analogue of Biot-Savart's law for electric current, except that in the magnetic case we shall take E as counterclockwise when H in the electric case is clockwise. (We do not really need any physical justification for this assumption, provided it is used only to find a solution of Maxwell's equations *a*, *b*, *c*, *d* which satisfies the assumed boundary conditions. Such use of this assumption would not differ in principle from the familiar use of the assumption that $y = e^{\beta x z}$ when solving the differential equation $d^3y/dx^3 + a^3y = 0$.) The Biot-Savart law for magnetic current can be advocated on the following purely physical grounds: if a displacement current $\partial E/\partial t$ can produce a magnetic field just as an electric conduction current does, then why should not a magnetic conduction current produce an electric field just as a magnetic displacement current $\partial H/\partial t$ does? From this assumption it follows at once that the work involved in carrying a unit electric charge around magnetic current $(i^* l)$ is $4\pi(i^* l)$. By applying the reasoning which was used in connection with Figure 14, we find that $2lE_p = c \cdot 4\pi(i^* l)$, and hence $E_p = 2\pi c i^*$ in Gaussian units. The electric field of i^* will now cancel E_p when the field of σ^* cancels H_n. Thus we arrive at the following result: an electric-current sheet of density $i = (c/2\pi)H_p$ and with lines of flow perpendicular to H_p produces a magnetic field which exactly cancels the parallel component of the actual H on one side and in the vicinity of S.

The electric charge $\sigma = (1/2\pi)E_n$ produces an electric field which cancels the normal component of E.

Magnetic charge $\sigma^* = (1/2\pi)H_n$ cancels the normal component of H. Finally, the magnetic-current sheet of density $i^* = (1/2\pi c)E_p$ cancels the parallel component of E.

In addition, i and σ as well as i^* and σ^* satisfy the equations of continuity.

We shall now go back to the wave guide of Figure 12. If the aperture of the guide is closed by a surface S which carries currents i and i^* and charges σ and σ^* as already defined, there will be neither a magnetic nor an electric field just outside S. *If there are no currents on the outer metal surfaces of the guide*, there will be no field anywhere in space. The current and charge distributions along S will have produced an equal and opposite field to that of the waves emerging through the aperture.

In order to find the original field at $P(x, y, z)$, we need only to calculate the field of our currents and charges on S and then reverse the sign.

The magnetic field of current density i is found directly from equations 17 and 18 of method 1.

$$H = \text{curl } A, \qquad A = \frac{1}{c}\int\int_S \frac{[i]}{r}\,dS \tag{74}$$

The electric field of electric-current density i and electric-charge density σ is given by equations 27, 19.

$$E = -\frac{1}{c}\frac{\partial A}{\partial t} - \text{grad } V, \qquad V = \int\int_S \frac{[\sigma]}{r}\,dS \tag{75}$$

Since the electric field E of magnetic current i^* was assumed to be in accordance with the Biot-Savart law except for the minus sign

$$E_{i^*} = -\text{curl } A^*, \qquad A^* = c\int\int_S \frac{[i^*]}{r}\,dS \tag{76}$$

Since the magnetic field of a magnetic charge is in accordance with Coulomb's law, we may apply the same reasoning which was used to obtain the electric field of electric charges to calculate the magnetic field of magnetic charges. The result is

$$H_{\sigma^*} = -\text{grad } V^*, \qquad V^* = \int\int_S \frac{[\sigma^*]}{r}\,dS \tag{77}$$

As in the electric case, this is not the total field but only the part produced by the magnetic charges. There is another part which comes about as follows: Magnetic-current density i^* produces electric field E_{i^*} which is given by equation 74. This electric field E_{i^*} results in

displacement current $\partial E_{t*}/\partial t$. The magnetic field of this displacement current has not yet been taken into account. The relation between a displacement current and its magnetic field is

$$\text{curl } H = -\frac{1}{c}\frac{\partial E_{t*}}{\partial t}$$

Since

$$E_{t*} = -\text{curl } A^*$$

we have

$$\text{curl } H = \text{curl}\left(-\frac{1}{c}\frac{\partial A^*}{\partial t}\right) \tag{74}$$

From which $H = -1/c\ \partial A^*/\partial t +$ (gradient of any vector). We already know from equation 77 what the second term on the right-hand side should be. The total H produced by the i^* and σ^* is therefore

$$H = -\frac{1}{c}\frac{\partial A^*}{\partial t} - \text{grad } V^* \tag{78}$$

The total field produced by i, i^*, σ, and σ^* can now be obtained by simple addition.

Total $H = H$ from equation 74 $+ H$ from equation 78
Total $E = E$ from equation 75 $+ E$ from equation 76

A considerable amount of work may be saved by making use of equation 42, div $A + (1/c)(\partial V/\partial t) = 0$. This is particularly true when the fields are sinusoidal functions of time, for then equation 42 becomes:

$$V = -\frac{c}{j\omega}\,\text{div } A \tag{79}$$

This result enables us to calculate V from A by differentiation which usually is much simpler than integration. The use of equation 42 can lead to no contradictions, because i and σ satisfy the equation of continuity.

Further saving of labor can be accomplished by making use of the fact that also

$$\text{div } A^* + \frac{1}{c}\frac{\partial V^*}{\partial t} = 0 \tag{80}$$

This equation is an exact analogue of equation 42. It can be proved by a process which amounts to a repetition of the proof of equation 42. When $\partial V^*/\partial t$ can be replaced by $j\omega V^*$, equation 80 saves us the integration for V^*.

The following is a summary of the simplified equations:

$$H = \text{curl } A - \frac{j\omega}{c}A^* + \frac{c}{j\omega}\,\text{grad (div } A^*) \quad \text{[electromagnetic units]} \tag{81}$$

$$E = -\frac{j\omega}{c}A + \frac{c}{j\omega}\,\text{grad (div } A) - \text{curl } A^* \quad \text{[electrostatic units]} \tag{82}$$

$$A = \frac{1}{c}\int\int\frac{[i]}{r}dS, \qquad A^* = c\int\int\frac{[i^*]}{r}dS \tag{83}$$

The magnitude of $i = (c/2\pi)H_p$ and $i \perp H_p$

The magnitude of $i^* = (1/2\pi c)E_p$ and $i^* \perp E_p$

The last two relations may be written in vector notation:

$$i = (n \times H)\frac{c}{2\pi}, \qquad i^* = -(n \times E)\frac{1}{2\pi c}$$

where n is a unit vector normal to surface S and pointing into the guide.

The use of equations 42 and 80 accomplishes somewhat more than a mere saving of labor. These equations implicitly contain the conditions of continuity which i and σ and also i^* and σ^* must satisfy along surface S as well as on the edges of surface S. When we calculate V and V^* from equations 42 and 80, we can be sure that the continuity conditions have been taken properly into account. On the contrary, when we calculate V and V^* directly from 75 and 77, we should make sure that σ and σ^* are consistent with i and i^*. This advantage is very real, because in practical applications it is often necessary to assume that S is not a closed surface but is only a portion of a closed surface. Under such conditions we must provide magnetic and electric line charges along the boundary of S, in order that the integrals for potentials be *extended over all charges and currents*, and so that the continuity conditions be satisfied on the boundary. The potentials of such line charges are not automatically included in V and V^* when these potentials are calculated directly from surface integrals. The potentials of the line charges have to be calculated separately by taking line

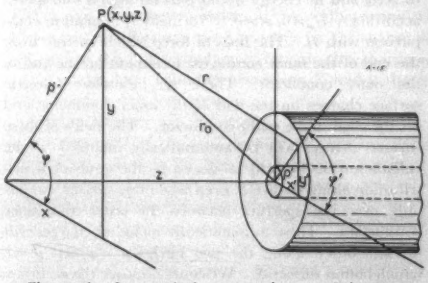


Figure 15. Open end of a concentric transmission line

integrals along the boundary of S, and these have to be added to V and V^*. All of this trouble is saved when V and V^* are calculated from equations 42 and 80.

In order to illustrate the application of this method let us calculate the radiation field of an open end of a concentric transmission line. For this purpose, let us take as surface S that portion of the $x\,y$ plane in Figure 15 which is included between the outer and inner conductors of a concentric transmission line. We shall assume that along surface S the electric field is radial (just as it is inside the pipe at some distance from the open end) and that the lines of magnetic field are concentric circles around the axis of the conductors.

Let b be the radius of the outer conductor; let a be the radius of the inner conductor. Let x', y' be the co-ordinates of a point along surface S. Let x, y, z be the co-ordinates of a point P in space. Let

$$\rho' = \sqrt{x'^2+y'^2} \qquad \frac{x'}{\rho'} = \cos\varphi' \qquad \frac{y'}{\rho'} = \sin\varphi'$$

$$\rho = \sqrt{x^2+y^2} \qquad \frac{x}{\rho} = \cos\varphi \qquad \frac{y}{\rho} = \sin\varphi$$

$$r_0 = \sqrt{x^2+y^2+z^2} \qquad \frac{\rho}{r} = \cos\theta$$

In accordance with our assumptions, along S

$$E_\rho = \frac{Q}{\rho'}\epsilon^{j\omega t}$$

where Q is such that $\int_a^b E_\rho d\rho = v =$ the difference in voltage between the inner and outer conductors; hence $Q = v/(\log b/a)$. The other components of $\boldsymbol{E}$ are $E_\varphi = E_z = 0$.

The components of the magnetic field are: $H_z = 0$, $H_\rho = 0$, $H_\varphi = (R/\rho)\epsilon^{j\omega t}$. The value of R in this expression is related to the charging current I which flows from the inner conductors into space. This charging current consists of two parts, I_1 and I_2. Current I_2 is a pure displacement current which is in quadrature with E_ρ. Current I_1 is in phase with E_ρ. Current I_1 cannot be zero, for if it were the normal component of the Poynting vector $(c/4\pi)\boldsymbol{E}\times\boldsymbol{H}$ along S would be equal to zero, and no energy would pass through S into space; accordingly $H_\varphi \neq 0$, $R \neq 0$. Normally I_1 is small in comparison with I_2. The lines of force which emerge from the end of the inner conductor terminate on the end of the outer conductor. There are, therefore, electric surface charges on the end of the inner conductor and on the edge of the outer conductor. The fields of these surface charges will be automatically included in the calculation of the field produced by the equivalent distribution along surface S, even when this surface extends only over the aperture between the outer and inner conductors. These automatically included charges will be distributed along the two circles $\rho' = a$ and $\rho' = b$ which bound surface S. We could improve the accuracy slightly by extending surface S over the entire xy plane. This alternative has no great advantage, since it requires exact information in regard to the distribution of charges on the edges of the two conductors, and these distributions are not known in much greater detail than that taken into account when S extends only over the aperture. We shall therefore proceed on the assumption that S extends over the aperture.

Since $H_\rho = 0$, H_φ is the only component along S; therefore $H_y = H_\varphi$ and $i = (c/2\pi)H_\varphi$. Current i flows at right angles to H_φ, so that $i = i_\rho = (1/2\pi)H_\varphi$, $i_\varphi = 0$; $i_x = i_\rho \cos\varphi'$, $i_y = i_\rho \sin\varphi'$ and

$$A_z = \frac{1}{c}\int\int\frac{[i_x]}{r}\,dS = \frac{1}{c}\int\int\frac{[i_\rho]}{r}\cos\varphi'\,dS$$

$$A_y = \frac{1}{c}\int\int\frac{[i_\rho]}{r}\,dS = \frac{1}{c}\int\int\frac{[i_\rho]}{r}\sin\varphi'\,dS$$

$$A_x = 0$$

Cylindrical co-ordinates are more convenient:

$$A_\varphi = 0$$

from symmetry and

$$A = A_\rho = A_x\cos\varphi + A_y\sin\varphi = \frac{1}{c}\int\int\frac{[i_\rho]}{r}\cos(\varphi'-\varphi)\,dS$$

Since

$$[i_\rho] = \left[\frac{c}{2\pi}H_\varphi\right] = \frac{Rc}{2\pi\rho}\epsilon^{j\omega t - jkr}$$

we have

$$A = \frac{Rc\epsilon^{j\omega t}}{2\pi}\int_a^b\int_0^{2\pi}\frac{\epsilon^{-jkr}}{r}\cos(\varphi'-\varphi)\,\rho\,d\rho\,d\varphi$$

where

$$k = \frac{\omega}{c}, \qquad r = \sqrt{(x'-x)^2+(y'-y)^2+z^2}$$

The value of A^* is found by a similar process. This time $i^* = (1/2\pi c)E_\rho$ and $i^* \perp E_\rho$ so that $i_\rho = 0$

$$i_\varphi{}^* = i^* = \frac{1}{2\pi c}E_\rho = \frac{Q}{2\pi c}\frac{1}{\rho}\epsilon^{j\omega t}; \quad i_x{}^* = -i_\varphi{}^*\sin\varphi', \; i^* = +i_\varphi{}^*\cos\varphi'$$

$$A_\rho{}^* = 0 \text{ by symmetry}$$

$$A_\varphi{}^* = -A_x{}^*\sin\varphi + A_y{}^*\cos\varphi$$

and

$$A^* = A_\varphi{}^* = c\int\int\frac{[i_\varphi{}^*]}{r}\cos(\varphi'-\varphi)\,dS$$

$$A_\varphi{}^* = \frac{Qc\epsilon^{j\omega t}}{2\pi}\int_a^b\int_0^{2\pi}\frac{\epsilon^{-jkr}}{r\rho}\cos(\varphi'-\varphi)\rho'\,d\rho'\,d\varphi'$$

The integrals for A_ρ and $A_\varphi{}^*$ become very simple if we assume that b is small in comparison with both λ and r, and that λ is small in comparison with r. In this case if $r_0 = \sqrt{x^2+y^2+z^2}$,

$$r = \sqrt{(x-x')^2+(y-y')^2+z^2}$$

$$\approx r_0 - \frac{xx'}{r_0} - \frac{yy'}{r_0}$$

$$\approx r_0 - \frac{\rho}{r_0}\frac{x}{\rho}x' - \frac{\rho}{r_0}\frac{y}{\rho}y'$$

$$\approx r_0 - \rho'\sin\theta(\cos\varphi\cos\varphi' + \sin\varphi\sin\varphi')$$

$$\approx r_0 - \rho\,\sin\theta\cdot\cos(\varphi'-\varphi)$$

and

$$\frac{1}{r} = \frac{1}{r_0}\left[1 + \frac{\rho'}{r_0}\sin\theta\cos(\varphi'-\varphi)\right]$$

$$\epsilon^{-jkr} = \epsilon^{-jkr_0}\cdot\epsilon^{jk\rho'\sin\theta\cos(\varphi'-\varphi)}$$

$$\approx \epsilon^{-jkr_0}[1 + jk\rho'\sin\theta\cos(\varphi'-\varphi)]$$

$$\frac{1}{r}\epsilon^{-jkr} \approx \frac{\epsilon^{-jkr_0}}{r_0}[1 + jk\rho'\sin\theta\cos(\varphi'-\varphi)]$$

If we introduce this approximate value of $(1/r)\epsilon^{-jkr}$ into the integral for A we get

$$A=\frac{R\epsilon^{j\omega t-jkr_0}}{2\pi r_0}\int_a^b\int_0^{2\pi}[1+jk\rho'\sin\theta\cos(\varphi'-\varphi)]\cos(\varphi'-\varphi)\times d\rho'd\varphi'$$

$$=\frac{jkR\epsilon^{j\omega t-jkr_0}}{4r_0}(b^2-a^2)\sin\theta$$

An almost identical calculation gives us

$$A^*=A_\varphi{}^*=\frac{jkQ\epsilon^{j\omega t-jkr_0}}{4r_0}(b^2-a^2)\sin\theta$$

In order to calculate div $\boldsymbol{A}$ and div $\boldsymbol{A}^*$, curl $\boldsymbol{A}$ and curl $\boldsymbol{A}^*$, it is best to resolve $\boldsymbol{A}$ and $\boldsymbol{A}^*$ into their components in spherical co-ordinates A_{r_0}, A_{φ_0}, A_θ. Since $A=A_\varphi$ and $A^*=A_\varphi{}^*$ we have

$A_{r_0}=A_\varphi\sin\theta$ $\qquad$ $A_{r_0}{}^*=0$

$A_\theta=A_\varphi\cos\theta$ $\qquad$ $A_\theta{}^*=0$

$A_\varphi=0$ $\qquad$ $A_\varphi{}^*=A$

and

$$\text{div } A=\frac{1}{r_0^2}\frac{\partial(r_0^2A_{r_0})}{\partial r_0}+\frac{1}{r_0\sin\theta}\frac{\partial}{\partial\theta}(A_\theta\sin\theta)+\frac{1}{r_0\sin\theta}\frac{\partial A_\varphi}{\partial\varphi}$$

$$=-\frac{(jk)^2R\epsilon^{j\omega t-jkr_0}}{4r_0}(b^2-a^2)\sin^2\theta+\text{ terms of order }\frac{1}{r_0^2}$$

$$\text{div } A^*=0$$

$$(\text{curl } A)_{r_0}=\frac{1}{r_0\sin\theta}\left[\frac{\partial}{\partial\theta}(\sin\theta A_\varphi)-\frac{\partial A\theta}{\partial\varphi}\right]=0$$

$$(\text{curl } A)_\theta=\frac{1}{r_0}\left[\frac{1}{\sin\theta}\frac{\partial A_r}{\partial\varphi}-\frac{\partial}{\partial r_0}(r_0A_\varphi)\right]=0$$

$$(\text{curl } A)_\varphi=\frac{1}{r_0}\left[\frac{\partial}{\partial r_0}(r_0A_\theta)-\frac{\partial A_r}{\partial\theta}\right]$$

$$=-\frac{(jk)\epsilon^{j\omega t-jkr_0}}{4r_0}(b^2-a^2)\sin\theta\cos\theta+\text{terms of order }\frac{1}{r_0^2}$$

$$(\text{curl } A^*)_{r_0}=0$$

$$(\text{curl } A^*)_\theta=\frac{(jk)^2\epsilon^{j\omega t-jkr_0}}{4r_0}(b^2-a^2)\sin\theta$$

$$(\text{curl } A^*)_\varphi=0$$

$$\text{grad}_{r_0}(\text{div } A)=\frac{(jk)^2R\epsilon^{j\omega t-jkr_0}}{4r_0}(b^2-a^2)\sin^2\theta+\frac{1}{r_0^2}\text{ terms}$$

$$\text{grad}_\theta(\text{div } A)=\frac{1}{r_0^2}\text{ terms only}$$

$$\text{grad}_\varphi(\text{div } A)=0$$

By substituting these values into equations 81 and 82 we obtain

$E_\varphi=0$

$E_r=0$

$$E_\theta=-\frac{(jk)^2\epsilon^{j\omega t-jkr_0}}{4r_0}(b^2-a^2)(R\sin\theta\cos\theta+Q\sin\theta)$$

$$H_\varphi=-\frac{(jk)^2\epsilon^{j\omega t-jkr_0}}{4r_0}(b^2-a^2)(R\sin\theta\cos\theta+Q\sin\theta)$$

$H_r=0$

$H_\theta=0$

It is well at this point to make the following observations: if the current which flows into the charge at the end of the inner conductor is $I=I_1+jI_2$, the magnetic field $\boldsymbol{h}$ of this current near the end of the conductor is not $2I/c\rho$ but $I/c\rho$. This is particularly easy to see when the inner conductor is thin. In fact, since ρ is small in comparison with λ we may, in this case, calculate the magnetic field directly from the Biot-Savart law

$$h=\frac{1}{c}\int_0^\infty\frac{I\sin\theta}{z^2+\rho^2}dz=\frac{1}{c}\int_0^\infty\frac{I\rho dz}{[z^2+\rho^2]^{3/2}}=\frac{I}{c\rho}$$

When this same integration is extended from $-\infty$ to $+\infty$, it results in the usual $2I/c\rho$. The result is easy to understand: one half of the conductor produces one half of the field.

By equating $h=I/c\rho$ with $H_\varphi=R/\rho$, we find that $I=cR$. It is interesting to compare current I which produces H_φ with the total equivalent current $2\pi ai$ which flows into the inner boundary of surface S. Since $i=(c/2\pi)H_\varphi$, and H_φ at $\rho=a$ is R/a, we see that $2\pi ai=Rc=I$. From this simple result one can draw the following conclusion: as the actual current I which flows into the actual charge at end of the inner conductor is equal to the "equivalent" surface current which flows into the boundary charge along the inner boundary of S, these two charges must also be equal. Since the field of this boundary charge is automatically included in the field of current and charge distribution along S, we do not need to add any additional terms to allow for the end charge on the inner conductor. A similar reasoning shows that no allowance need be made for the charge at the end of the outer conductor, because this charge is equal to the outer boundary charge on S, and is therefore already taken into account.

This conclusion can be verified by computing the scalar potential of the two ringlike charges by direct integration. If δ is the line density along the inner ring charge, $q=-2\pi a\delta$, then the scalar potential $V=(\epsilon^{j\omega t}\int_0^{2\pi}\delta\epsilon^{-jkr}/r)a\,d\varphi$. Similarly, the scalar potential of the ring charge on the outer conductor is $V'=(\epsilon^{j\omega t}\int_0^{2\pi}\delta'\epsilon^{-jkr}\times r)b d\varphi$ where δ' is such that $q=2\pi b\delta'$. The potential of both rings is $V+V'$. These integrations are easily carried out if ϵ^{-jkr}/r is expanded as before, except that this time it is necessary to keep three terms, because the first two cancel out. The result is

$$V+V'=q\frac{(jk)^2}{4r_0}\epsilon^{j\omega t-jkr_0}(b^2-a^2)\sin^2\theta$$

Since

$$\frac{\partial q}{\partial'}=2\pi ai=2\pi a\frac{c}{2\pi}\frac{Q}{a}\epsilon^{j\omega t}\qquad q=\frac{c}{j\omega}Q=\frac{1}{jk}Q$$

If we substitute this value of q into $V+V'$, we see that $V+V'$ is identical with $(1/jk)\text{div } \boldsymbol{A}$, which is exactly what is to be expected from equation 42.

The procedure for calculating the radiation resistance is substantially the same as that which was used to

calculate the radiation resistance of the dipole, except that this time we have yet to find the inphase component I_1 of current I. The total radiated power is

$$P=\frac{c}{8\pi}\int_0^{2\pi}d\varphi\int_0^{\pi}(E\times H)\cdot r_0\, r_0 \sin\theta d\theta$$

Since

$$R=\frac{I_1+jI_2}{c},\qquad P=\frac{c}{4}\frac{k^4}{16}(b^2-a^2)^2\left\{\frac{1}{c^2}(I_1^2+I_2^2)\frac{4}{15}+Q^2\frac{4}{3}\right\}^{\dagger}$$

This same power passes through surface S and can be calculated from the Poynting vector along S. Along this surface $H=H_\varphi=Q/\rho$, $E=E_\rho=R/\rho$, $H\perp E$.

The power passing through surface S therefore equals

$$P=\frac{c}{8\pi}\int_0^{2\pi}d\varphi\int_a^b H_\varphi E_\rho\,\rho d\rho=\frac{I_1}{4}Q\log\frac{b}{a}=\frac{I_1v}{4}$$

By equating the two expressions for the same power, we can calculate I_1 when voltage v between conductors and the quadrature charging current I_2 are known. Once I_1 has been found, we can evaluate the radiation resistance which may be defined in the following manner:

$$\left(\frac{I_1}{\sqrt{2}}\right)^2R=P=\frac{I_1v}{4}$$

CONCLUSION

We have described two methods which are used in making calculations of radiation fields. The first method is convenient for calculating the field of a radiator with a known current distribution. This method has been very helpful in the development of antennas. The second method is useful when the field near the radiator is known. This method is relatively new and is still somewhat in a state of flux. This method is replacing the Kirchhoff-Huygens procedure which has been used in early calculations of radiation from wave guides, electromagnetic horns, and so forth. Method 2 seems to be superior to the Kirchhoff-Huygens procedure, because in method 2 one is dealing with currents and charges which are familiar, whereas in the Kirchhoff-Huygens procedure one has to use a function, the physical meaning of which is not clear. A considerable number of erroneous results has been obtained by applying the Kirchhoff-Huygens procedure to problems involving apertures because of the difficulty of finding the proper function which must be added to take care of conditions along the boundary of an aperture.

In describing methods 1 and 2, it has been our aim to derive all expressions directly from physical concepts. Sometimes this was done at the expense of mathematical rigor.

† When either H or E or both are complex, one should keep in mind that $a+jb$ stands for $a\cos\omega t+b\sin\omega t$. This fact is used in calculating the time average over the cycle.

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Less Critical Materials in Critical Instruments

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ELECTRICAL instruments and various related measuring devices constitute the "critical components" of many different kinds of war equipment, such as ships, tanks, and airplanes. Although the material content of each unit of these "critical components" is relatively small compared with many other wartime products, the large quantities in which the devices are being manufactured to meet present production schedules require large aggregate amounts of material, most of which are of the "scarce" classifications. The necessity for conservation in the use of materials in instrument production is therefore a matter of great importance and one which has been and is being given careful attention at present.

Logically, the program for this material-conservation effort falls into six subdivisions as follows:

1. Use of alternate materials.
2. Adaptation of designs to use less material.
3. Development of new materials.
4. Utilization of scrap and secondary supplies.
5. Use of surplus stocks.
6. Conservation by improved workmanship.

These six ways of making the most efficient use of materials in instrument manufacture have been utilized in the West Lynn Works, of the General Electric Com-

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pany, and substantial savings of critical materials have been achieved thereby.

In planning the conservation program certain limitations and complications had to be considered. Not only are instruments and related devices now being produced in unprecedented quantites—as vital components of aircraft, ships, electronic products, and many other modern implements of war—but they are needed also, though in smaller quantities, in essential war industries to improve efficiency, expand productivity, save materials, and protect manufacturing facilities. It is, therefore, neither wise nor advantageous to substitute less scarce alternates at the expense of quality and performance—a temporary expedient which can be resorted to in the case of a number of civilian products.

The experience of a manufacturer of combat instruments and other electrical measuring devices, many of which are "critical components" of fighting equipment, shows that worth-while contributions to the war effort can be achieved by a well-rounded material-conservation program.

On the contrary, rigorous conditions of modern warfare with wide extremes of temperature, severe vibration, and high shock require performance in many ways superior to that demanded of most peacetime applications. These conditions, translated into the exacting Army and Navy specifications to which combat instruments must conform, have the effect of limiting the number of kinds of materials that can be used for specific purposes. Although the armed forces, with the co-operation of the manufacturers involved, have made substantial progress in revising specifications to allow a wider choice of materials and to encourage conservation, it is obvious that any action jeopardizing the service performance and the dependability of a device must be avoided at all cost.

The material-conservation program for electrical measuring devices is complicated, in addition, by the fact that these devices require many different kinds of critical materials. For example, the long-scale, concentric-magnet-type voltmeter for switchboards, shown in Figure 1, uses the materials listed in the caption. The quantity of each material is of course small, as the complete instrument weighs only $3^3/_4$ pounds. Other measuring devices have used, in addition to those listed, such scarce constituents as magnesium, tantalum, molybdenum, platinum, mica, tung oil, toluol, and many more. It is difficult to find an item on the War Production Board's list of most critical materials which has not been used at least in small amounts in a well-rounded line of electrical measuring equipment.

In spite of the limitations and complications involved in conserving critical materials for electrical measuring devices, large savings already have been made, and more will result as projects still in development reach the stage of practicable manufacture.

USE OF ALTERNATE MATERIALS

The use of less scarce alternates is perhaps the most straightforward conservation measure, although such changes often involve rather extensive design and process modifications in order to assure continued good performance and high quality. Watt-hour meters, for example, were subjected to a thorough conservation study even before Pearl Harbor because of their relatively large use of aluminum, the first material to become critical. Figure 2 shows a typical domestic meter and indicates the alternate materials that have been used.[1] For each part originally made or finished with aluminum, copper or its alloys, tin, nickel, or other critical materials, alternates were tested and evaluated carefully with respect to both suitability and future availability. As a result, the alternates were introduced with no appreciable change in watt-hour-meter characteristics or useful life and without interruptions in manufacture. Net annual savings in watt-hour meters of the types produced in the West Lynn Works amounted to approximately 1,000,000 pounds of aluminum, 130,000 pounds of copper, 45,000 pounds of nickel, 3,400 pounds of cadmium, and 2,000 pounds of tin. In addition, critical constituents of varnishes and plastics were changed to conserve sizable quantities of toluol and formaldehyde.

These savings are based on the rate at which these watt-hour meters were being produced when the alternate materials were introduced during the last half of 1941 and early in 1942. Subsequently, the tremendous requirements of the war program caused severe shortages of the remaining materials, particularly of copper, which could not be removed entirely from the meter and which was the only practical substitute for aluminum for certain parts. To make these materials available for fighting equipment, a drastic curtailment of watt-hour-meter production was effected by the War Production Board, despite the great value of these devices as a means of conserving electric energy. Nevertheless, the experience of introducing alternates, to save critical materials in these devices without jeopardizing performance, has been extremely valuable in planning conservation programs for more critically needed measuring equipment.

Obviously, all the changes made to conserve material in wartime electrical instruments and associated equipment cannot be included in this review, but a few examples are worth noting. The aluminum previously used for many housings, cases, and supporting frames has been replaced wherever practical by cast iron, fabricated steel, die-cast zinc, sheet zinc, cast secondary bronze, or other materials, as determined by the requirements of the application. In each instance the least critical material which satisfied the requirements was chosen, after samples were tested for stability, expansion with temperature, magnetic effects, and other characteristics essential to maintaining the high-quality per-

Figure 1. Long-scale d-c voltmeter for switchboards

Materials used in the switchboard voltmeter:

Aluminum
Copper
Brass
Phosphor bronze
Cobalt
Tin
Zinc
Nickel
Lead
Carbon steel
Alloy steel
Iron
Sapphire
Fiber
Cork
Silk
Rayon
Shellac
Ivory
Ceramic material
Phenolic plastic
Methyl methacrylate plastic
Synthetic insulations
Photographic paper
Miscellaneous organic finishes

formance of the device. Since the alternate materials are usually less resistant to corrosion than the original aluminum, adequate protective finishes were selected to render the completed parts as impervious to corrosive action as aluminum. The new parts do, of course, weigh somewhat more than the old ones, but because of the comparatively small size of most instrument parts this change should not cause difficulty. Of far greater importance is the fact that this year these instruments will not use over 50,000 pounds of aluminum that would otherwise have been required at this plant.

Similarly, either zinc, decalcomanias, or fiber have replaced aluminum and brass for rating plates; brass supporting studs and plates have been changed to steel; and carbon steel has been substituted for stainless where corrosion and magnetic conditions permitted. Nickel, tin, and cadmium platings, and aluminum lacquer continue to be used only where really necessary for functional reasons and in many instances have been replaced by silver, zinc, or more available sprayed finishes. Critical nonmetals such as rubber have been changed first to reclaimed grades and then in certain cases to the more available synthetic types. The lower grades of domestic mica have been used in place of the scarce imported varieties. The use of shellac and silk has been drastically curtailed by the utilization of synthetic varnishes and textiles, and tung oil and toluol have been eliminated.

In an effort to save the relatively small amounts of tin used in solder, all soldering operations were investigated carefully, with several interesting results. It was found that in a number of cases the substitution of welding or brazing not only saved the tin but also provided stronger more permanent connections. In other applications where the parts to be joined are relatively large, it has been possible to reduce the tin content of the solder from 40 or 50 per cent to 20 per cent without impairing the quality of the joints. However, for ultrafine wire, which is used in instruments in sizes as small as 0.001 inch in diameter, and for other delicate parts such as control springs, lowering of tin content requires a sufficient increase in soldering iron temperature to damage these parts. Moreover, the prime importance of sound soldered joints, the difficulties inherent in soldering these small parts, and the necessity of training hundreds of new employees for expanded production emphasize the wisdom of using the most satisfactory solder, irrespective of tin content, for such applications.

ADAPTATION OF DESIGNS TO USE LESS MATERIAL

Conservation by the use of alternates, while of great value in channeling the most critical materials to the most vital war needs, is definitely limited. The resulting use of the alternate materials can easily increase sufficiently to make them almost as scarce as the originals which they replace. Moreover, for many uses the possible alternates are relatively few. In electrical measuring devices, the copper used for conductors is an excellent example of this situation. For nearly every application the only alternates that can be considered are aluminum and silver. Aluminum is ruled out immediately, because it is even scarcer than copper, and silver can be obtained in such relatively small quantities that any large-scale substitution of it for copper would rapidly exhaust the entire supply of silver. Nevertheless, copper stands high on the list of materials which are available in insufficient amounts for war demands and, therefore must be conserved. This can be accomplished only by designing to use less copper.

An excellent example of what can be accomplished to conserve materials by this approach is the redesign of a line of indoor dry-type instrument transformers to use

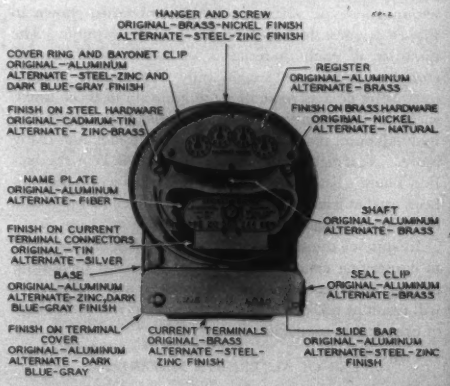

Figure 2. Original and alternate materials used in single-phase watt-hour meters

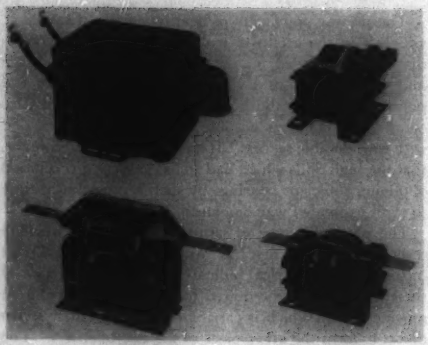

Figure 3. New material-saving potential and current transformers (right) compared with the types they replaced (left)

less copper and steel.[2] A detailed analysis of applications and specifications showed that a substantial portion of the orders for these devices was being filled by supplying transformers with either higher accuracies or greater capacities than required. It was concluded, therefore, that, if instrument transformers were designed to meet but not exceed the requirements of special applications, and if these designs could be put in production without appreciable retooling, large amounts of both copper and steel would be saved. Such a program is well under way, and designs for six types have been completed. Although these were introduced in the latter part of 1942, they have already reduced copper usage by over 100,000 pounds and steel by about 140,000 pounds. It is expected that in 1943 a total of 130,000 pounds of copper and 173,000 pounds of steel will be saved by applying the new designs to special applications.

The potential and current transformers shown on the right-hand side of Figure 3 are typical of these six designs which do the job with less material. At the left, for comparison, are the standard types which were supplied previously for marine switchboards, when such applications were few, materials were plentiful, and the introduction of nonstandard types was not justified. In addition to using far less copper and steel, the new transformers are better able to withstand the high shocks and rough service of modern sea warfare because of their compact rugged construction, and they meet Navy specifications in all respects. Each of the six designs was laid out to use existing equipment, so that only a few pounds of steel were required for simple drill jigs and similar tools in order to start large-scale production.

Instruments themselves have also been designed to use less material. A recently developed dual tachometer for aircraft conserves both space and material by providing in one instrument the indication that previously required two instruments of about the same size. Approximately 16 square inches of the aircraft instrument panel are thus released for other essential needs. The material savings resulting can be illustrated best by the fact that the authors' plant, which is just one of the several manufacturers of this design, expects to use this year 33,000 pounds less aluminum than would be required to provide equivalent instrumentation with the older single-element design.

A novel construction[3] and the use of new materials enable the pointer of the concentric-magnet switchboard instrument, of the type shown in Figure 1, to move through an angle of 240 degrees. A 6.8-inch scale length is thus obtained in an instrument $4^1/_4$ inches square to provide greater ease of readability in a relatively small area. A complete line of these instruments was designed to supersede the more conventional $5^1/_2$-inch rectangular construction having 105-degree scale arcs. In Figure 4, a comparison of these two types shows that the newer design requires about 33 per cent less space, and at the same time its scale length is 35 per cent longer. In addition to the material savings in the switchboard structure resulting from the compactness of these designs, the amount of critical materials to be used in producing the

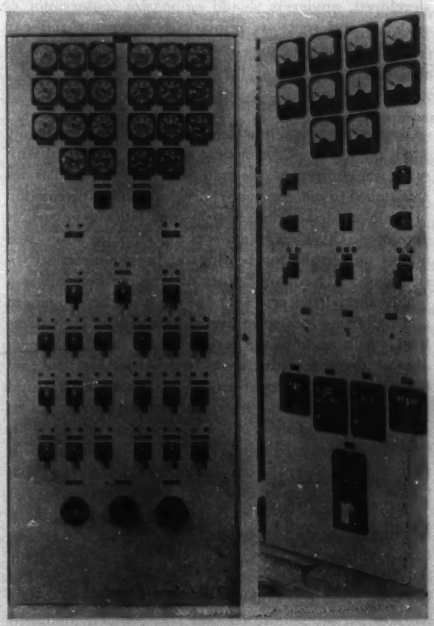

Figure 4. Switchboard panel equipped with concentric-magnet instruments (left) compared with a panel using the older types of instruments (right)

Figure 3. Glass Vee jewels for miniature instruments

1943 output will be approximately 30,000 pounds less than that necessary for a corresponding number of the $5^1/_2$-inch rectangular types. Moreover these long-scale instruments recently have been modified to withstand unusually severe war conditions, thus eliminating the need, this year, for 137,000 pounds of the soft pure rubber in which previous designs were mounted.

The preceding examples serve to point out that, wherever new electrical measuring devices are being developed, engineers should emphasize conservation of material and space as primary requirements and can make substantial savings by designing to use less material and space.

DEVELOPMENT OF NEW MATERIALS

Because electrical measuring devices require relatively small quantities of the critical materials compared with other war equipment, the material shortage alone has not threatened to place serious restrictions on the production of vitally needed combat instruments, with one important exception. This exception was the sapphire jewel used almost universally for bearings in prewar electrical instruments. The manufacture of sapphire bearings is a highly specialized art, with the bulk of the equipment and skill being located in Europe, principally in Switzerland. As a result of the curtailment of the supply from abroad, together with the vastly expanded war demand for instruments, a threat arose that this material would run out or at least that instrument production would be restricted to numbers far below indicated needs. This situation necessitated an approach to material conservation quite different from those previously described. Obviously a new material was needed.

The requirements of a material to replace sapphire instrument jewels are unusually exacting for the reason that high instrument accuracy depends to a large extent on the dimensional precision and low friction of the bearings. Moreover, the material must be sufficiently hard to permit minute contact areas, which minimize friction torque, and at the same time withstand severe wartime service without damage that would impair performance.

The prewar popularity of bearing made of sapphire, which is in the group of materials next in hardness to diamond, depended on the ingenious, though delicate and tedious, methods developed abroad for grinding and polishing it. Establishing similar processes in this country was of course possible and has in fact proceeded with considerable success. It has been obvious, however, that the high skills which had to be developed precluded obtaining sufficient bearings by such a program in time to meet expanded war demands.

The particular type of sapphire bearing for which a severe shortage was first felt was the small Vee jewel used in small panel electrical indicating instruments. Two of these Vee jewels are required to support the instrument moving system which is carried on two extremely sharp pivots to form the other parts of the two bearings. The extremely small radii of the spherical ends of the pivots, designed to keep the effect of friction at a minimum, cause bearing pressures of the order of several hundred thousand pounds per square inch when the moving system is in a vertical position.[4] The need for hard bearing materials to resist deformation when the instrument is subjected to impacts is obvious.

In developing new bearings which would replace adequately the sapphire Vees and could be made available rapidly in large quantities, the experience of some 25 years ago with glass jewels has been a substantial help.[5] Such jewels were used at that time because of the unsatisfactory dimensional characteristics of the sapphire Vees then obtainable. Improvements in the sapphire cutting technique subsequently led to abandoning the glass jewels, which at the time were thought to be too soft to be entirely satisfactory in their resistance to impact.

As a shortage of sapphire Vees became imminent, intensive investigation and development were started at the plant with which the authors are associated to determine the best material available, to evaluate its performance compared with that of sapphire, and to design and build satisfactory mass-production equipment capable of meeting the ever-increasing demands. The progress made by the glass industry during the past few years in making new types of harder glass was used to advantage. As the result of many tests, a material was chosen which could be formed in semiautomatic machines to provide very smooth highly polished bearing surfaces of accurate dimensions.

This hard glass has been shown to have a coefficient of friction within the range of the sapphire previously used, and measurements of jewel roll indicate that it is at least equivalent if not superior to sapphire in this respect. Although the hardness of the new glass jewel is not as high as that of sapphire, it is entirely adequate for small panel instruments, since the greater hardness of sapphire is of no appreciable advantage in instruments having moving systems weighing less than 0.75 gram. As a result, the over-all performance of such instruments

equipped with glass jewels is equivalent in every way to that of the same types built with sapphire.

Once a material was found to replace sapphire Vees with no sacrifice in small-panel-instrument performance, equipment was developed rapidly, and production of the glass jewels shown in Figure 5 was stepped up to a point which eliminated the possibility of restrictions on instrument output caused by a shortage of Vee jewels. At present, virtually all small panel instruments in the country are manufactured with glass bearings instead of sapphire, and over 80 per cent of the total demand for instrument Vee jewels is being supplied by the use of glass.

The development of glass Vees in quantity production was followed closely by similar activity to provide hard glass ringstones for use in place of sapphire ringstones, a shortage of which threatened to restrict the manufacture of certain types of combat instruments. Ringstones are required in these instruments for various journal bearings and must be held to extremely close tolerances. As in the case of the Vees, the glass ringstones can replace their sapphire predecessors without perceptible sacrifice of instrument performance and lend themselves to quantity production methods. The development of these two types of hard glass jewels, together with domestic processing of sapphire jewels as developed, by various specialty manufacturers, for larger instruments in which glass would affect performance adversely, has enabled the wartime instrument industry to be practically independent of foreign sources and to expand with unprecedented speed.

UTILIZATION OF SCRAP AND SECONDARY SUPPLIES

Using collected scrap in the making of Alnico permanent magnets for instruments is another method of conserving materials. This high-energy alloy material which has been developed rapidly during the past few years has contributed substantially to the new compact instruments with improved performance shown in Figures 1 and 4 and to many other recent designs.[6] Figure 6 illustrates a number of types of Alnico permanent magnets which currently are being cast and finished for electrical measuring devices.

The Alnico alloy, as its name implies, is cast from a melt made of aluminum, nickel, and cobalt, as well as other materials, depending on the type. One of the most commonly used types, Alnico II, contains approximately 10 per cent aluminum, 17 per cent nickel, 12½ per cent cobalt, 6 per cent copper, and the remainder iron. Because the magnetic strength and other qualities of Alnico magnets are very sensitive to variations in the proportions of these constituents, they must be controlled carefully and, prior to the war, were obtained by adding high-purity virgin metal to remelted Alnico sprues.[7] With the outbreak of hostilities, the need for developing additional secondary sources of material became apparent, and work to this end was undertaken at the plant with which the authors are connected.

Cobalt was the first to become scarce, because imports from refineries in Belgium were cut off by the German occupation of that country. A cobalt-bearing alloy, known as "crude cobalt" and containing in addition to cobalt approximately 43 per cent iron and 16 per cent copper, plus various impurities, was, however, made available by shipment from the Belgian Congo. To make use of this alloy, a method of removing the impurities and a new technique for combining the constituents of Alnico to utilize the iron and copper as well as the cobalt were developed. After the impurities were removed, an analysis was made of this master alloy, and it was balanced to the desired composition. The introduction of this process not only avoided any production delays caused by the scarcity of cobalt, but it actually resulted in an increase of magnet damping strength of almost ten per cent, as shown by the curve in Figure 7. The improvement must be attributed to the higher over-all purity of the Alnico.

Moreover this new method was well adapted to the use of secondary sources of nickel and aluminum, as the supply of these metals became critical. Turnings and punch-press skeletons of high nickel alloys were utilized first without serious problems arising. Because the available quantities of such scrap were insufficient, various worn-out and discarded nickel-bearing products were accumulated. These otherwise useless parts were refined in order to obtain from them additional nickel which could be utilized satisfactorily. For the aluminum requirements, arrangements were made to replace the virgin metal originally used with secondary aluminum which is considerably more plentiful. In addition, a process was developed for reclaiming the fine grinding dust occurring at the cutting off and other operations performed in finishing Alnico magnets. These grindings, together with miscellaneous Alnico foundry scrap which ordinarily was discarded, are now used to provide a substantial portion of the materials required. As a result practically all of the nickel, aluminum, and copper, and a large portion of the cobalt and iron needed for Alnico permanent magnets manufactured at the authors' plant are secured without drawing on the nation's virgin metal.

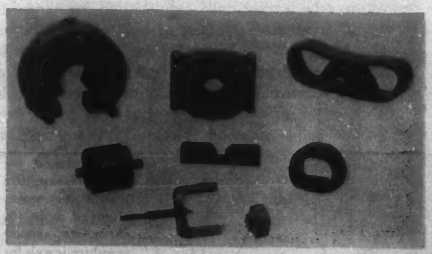

Figure 6. Typical Alnico II permanent magnets used in electrical measuring devices

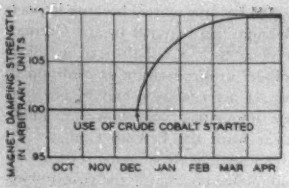

Figure 7. Change in Alnico-permanent-magnet damping strength after use of crude cobalt was begun

USE OF SURPLUS STOCKS

In these days of critical-material shortages, it is at times hard to understand the existence of certain surplus items. The necessity for converting many manufacturing plants to war production with great rapidity, however, precluded careful planning and has resulted in excess stocks of certain kinds of fabricated materials, semi-finished parts, and even completed products. Various units of the War Production Board have been successful in channeling these excesses to war industries, and manufacturers of electrical measuring devices have co-operated in this work. The latter have also been able to arrange the utilization of certain excess parts and devices of value only in the measurement field. For example, glass Vee jewels were developed and introduced in small panel instruments so rapidly that a considerable number of sapphire Vees, made originally for these instruments, were still available after the glass jewels were introduced. This surplus of sapphire jewels, therefore, was used for larger instruments, whose heavier moving systems required the greater hardness of sapphire—this being made possible by changing the design of the jewel setting as shown schematically in Figure 8. As a result, a shortage of sapphire Vees for these larger types has been avoided, at least until the domestic production of the larger sapphire jewels is adequate to meet the requirements.

Surplus stocks of the single-phase watt-hour meter, shown in Figure 2, were also adapted to meet war requirements. Restrictions as to types of installations for domestic electric-power consumers caused a sudden shift in demand from the three-wire type meters to the two-wire style, and existing stocks accumulated for anticipated requirements were out of balance with actual needs. Sets of conversion parts were, therefore, designed with which the three-wire meters could be converted readily for use on two-wire applications. One of these sets contains less than an ounce of copper, brass, and steel, and a few inches of insulation. With it, a meter of the three-wire type, which required 9.4 pounds of critical materials to build, can be changed, by using only a screw driver and pliers, so as to perform an essential service with complete satisfaction. These conversion sets are available to public utilities and thus surpluses of one type are utilized to relieve shortages of another.

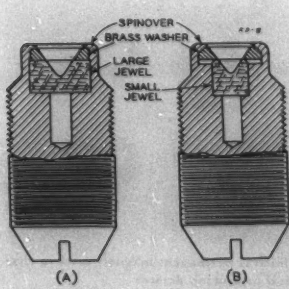

Figure 8. The older method for setting sapphire jewels (a) was changed as in (b) to utilize smaller sapphire jewels for heavier moving systems

CONSERVATION BY IMPROVED WORKMANSHIP

The five methods of critical-material conservation, previously described, have been undertaken chiefly by design engineers and material and process experts, with some assistance from purchasing and sales departments. To the sixth major method, however, everyone working in a manufacturing plant can make worth-while contributions. Large savings of critical materials would be made if every part produced met specifications and none were rejected and scrapped. Although such perfection is more than can be expected of any group, especially those engaged in manufacturing delicate high-precision measuring devices, much can be accomplished by emphasizing this possibility of conservation to all concerned. For this purpose, educational publicity methods have been used effectively, both nationally and by individual industrial concerns, to explain and encourage improved workmanship as a means of saving critical materials.

A well-co-ordinated program of this nature at the West Lynn Works has been fully justified. Since its inception in the latter part of 1941, improved workmanship has resulted in substantial reductions in the amount of scrap material per employee. In 1942, despite the rapid increase of new workers and the loss of many skilled men to the armed forces, these reductions resulted in savings equivalent to over 2,000 tons of critical materials and many thousands of productive man-hours. This experience shows that the decrease of spoilage factors in the manufacture of war equipment should not be overlooked as an effective material-conservation measure.

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Nikola Tesla's Achievements in the Electrical Art

"In the interval since Tesla did his really great creative work his name has been associated with so many projects of questionable scientific quality that I imagine they may have raised doubts in the minds of many as to his real achievements" (Doctor Frank B. Jewett in a letter dated January 1943). The Edison Medal (1916) was awarded by the AIEE to Tesla "for his early original work in polyphase and high frequency alternating currents."[13] To record his "real achievements," the accompanying two articles have been prepared by authors selected for their qualifying experience and professional standing.

I—TESLA'S CONTRIBUTION TO ELECTRIC POWER

CHARLES F. SCOTT
HONORARY MEMBER AIEE

FARADAY'S principle of electromagnetic induction discovered in 1831 after some 40 years of incubation resulted in practical forms of dynamo machines. Electricity from mechanical power (instead of costly batteries) stimulated invention of apparatus and the development of various methods or "systems" for distributing and utilizing the electric current. The evolution of "systems" culminated in Tesla's polyphase alternating current, with its unique induction motor. His system has dominated the development of electric service during a half century and continues today as our method of using electric power.

That was Tesla's contribution to electric power. Tesla's death in January last occurred in the semicentennial year of the demonstration of his polyphase system at the Chicago World's Fair and its adoption for the great Niagara project. It is the method in universal use today. We know no other. But the story of the pioneer years of electric light and power is needed to give perspective and reveal the real significance of the polyphase method.

After two score years, the dynamo; then in two eventful decades the trivial beginnings of the commercial electric light developed through the efforts of many workers and came to fruition in Niagara power, where the Tesla polyphase system achieved "the great step in the transition from mechanical power in industry to electric power everywhere"[1] and made possible our 20th-century power development. The years 1876, 1886, and 1896, serve as milestones marking these eventful decades.

1876

On Professor Elihu Thomson's 80th birthday anniversary (1933), I asked him just what electrical apparatus was at the Centennial Exposition in Philadelphia in 1876. "Well, I'll tell you," he said. "There was a Gramme machine from France that ran one arc lamp, and another wound for electroplating, and a Wallace dynamo that operated a lamp on top of the building." There was also at the exposition a dynamo designed by Professor W. A. Anthony.[2]

In 1928 the Franklin Institute celebrated the 50th anniversary of the first tests on the efficiency of a dynamo. Among the speakers were Charles F. Brush, whose dynamo was tested; Professor Thomson,[3] a teacher of science in the Philadelphia High School, who conducted the test; and his student assistant, E. W. Rice, later head of the General Electric Company. Brush, a Michigan graduate who had been keenly interested in the making of electrical apparatus from his high school days, had invented a new type of dynamo which could supply four arc lamps by four independent circuits, commercial sales of which had started early in 1878. He said, "It was in that year that I had the good fortune to invent and develop the modern series arc lamp with its regulating shunt coil. It made arc lighting from central stations commercially possible; and I think it may be regarded as marking the birth of the electric lighting industry." Dynamo and lamps were adapted to a con-

Charles F. Scott, past president AIEE (1902–03), was with Westinghouse Electric Company, 1888–1911; then professor of electrical engineering (now emeritus) at Yale University. He was assistant to Tesla, 1888–89. In Tesla's original type of motor with primary coils around individual poles he effected radical improvement by devising a slotted secondary with specially distributed winding. Motors of this type (about five horsepower) successfully operated coal-mining machines as described in his paper in January 1891 before the Engineers Society of Western Pennsylvania, its first paper on mining. His AIEE paper describing two single-phase installations, for lighting at Portland, Oreg., and for power at Telluride, Colo. (for the latter he made the general plan) presented in June 1892 was the institute's first paper on long-distance transmission. He participated in planning and preparation of apparatus for the Chicago World's Fair and for the original hydroelectric development at Niagara Falls. His two-phase–three-phase transformer connection, more commonly known as the Scott T connection ("Polyphase Transmission," National Electric Light Association, March 1894), was used in the transmission of three-phase current to Buffalo from the original two-phase generators. He was technical advisor to Edward Dean Adams in his preparation of the two volumes "Niagara Power" and has made a special study of the state of the art in the period when Niagara plans were crystallising. He was chairman of section *D*, electric power transmission, of the International Electrical Congress, St. Louis, Mo., 1904. His recent interest in electrical developments just preceding and during his own contact with them in the 1890 period have given a perspective view which he presents in the present paper.

stant-current series system; the usual current was about ten amperes, and the voltage increased about 50 volts as each lamp was added.

Following the Franklin Institute tests the Thomson–Houston arc-light system appeared; soon there were many others in vigorous competition for the lighting of streets and factories. To a limited extent motors were operated in series with arc lamps.

The constant-current (voltage varying with the load) system for operating motors is the method used in installations listed in Kapp's "Electric Transmission of Energy," 1890. Usually a generator and a single distant motor constituted the power transmission. At the Comstock mine in Nevada six 80-horsepower Brush motors received constant current over independent circuits from six generators and were belted to a single shaft for operating a stamp mill.[4]

Incandescent lamps could be operated on constant-current circuits if they had heavy filaments adapted to large currents and a few volts, or were connected in series-multiple. Practical difficulties inherent in the series connection were many. Edison saw the merits of a constant-potential circuit and the parallel connection of lamps, enabling them to be turned on and off like gas lights. He set about to make a high-resistance filament that would take a small current and thereby make possible conductors of permissible size. In 1879 he achieved a lamp and also the constant potential system which is the method in universal use today. His Pearl Street station in New York City opened September 4, 1882.

Ensign Frank J. Sprague, a few years out of Annapolis, was American member, and secretary of the jury of awards for electrical machines and lamps at the Crystal Palace Electrical Exhibition, London, 1882. In his elaborate report to the Navy[5] he describes about a dozen types of dynamos; evidently Edison's with "high-resistance" shunt field was the one particularly adapted to produce constant potential. Sprague says: "The Edison machines were designed to form part of a distinct and complete system of lighting and as such they possess some peculiar features not noted in other machines." In a paper before the British Association for the Advancement of Science on "Demands of a System of Electrical Distribution" he presents the new constant-potential system as best meeting these demands. In his painstaking report he describes many forms of arc and of incandescent lamps on exhibit, but no motors. There were none. On his return he pioneered the construction and introduction of motors on Edison circuits.

Electric cars were attempted by many pioneers in the '80's. Trial roads of a mile or so with one or more cars were followed by Sprague and his Richmond road calling for 40 cars, doubling the existing total in the United States.

1886

At Thanksgiving time in 1886 at Buffalo, N. Y. came a radical innovation—operation by alternating current. The new kind of current in small amount was transmitted at 1,000 volts and then transformed to 20 times the current for 50-volt incandescent lamps. While the Edison three-wire system was commercially limited by the cost of copper to about a half-mile radius, the new a-c system greatly extended the area that could be served.

Westinghouse had acquired the Gaulard and Gibbs alternating-constant-current system in 1885. At Pittsburgh what came from abroad was completely revamped, electrically and mechanically. William Stanley, the Westinghouse electrical expert, recognized the desirability of changing from constant-current to constant-potential operation; he was familiar with counterelectromotive force (he is said to have coined that term). His aim was a primary winding with sufficient counter electromotive force to permit transformers to be connected in parallel to a high-voltage circuit; for this he obtained an important patent.[6] Westinghouse, however, was concerned with securing a mechanical construction suited to manufacture. The form used in the early transformers was patented by him.[7]

The new transformer inspired confidence and Stanley proposed continuing the a-c development at Great Barrington, Mass. His successful demonstration of an operating system in March 1886[8] was followed by the design and manufacture at Pittsburgh of commercial apparatus and the inauguration of a-c service in Buffalo.

While alternating current overcame the distance handicap of direct current for incandescent lighting, it had no successful motor.

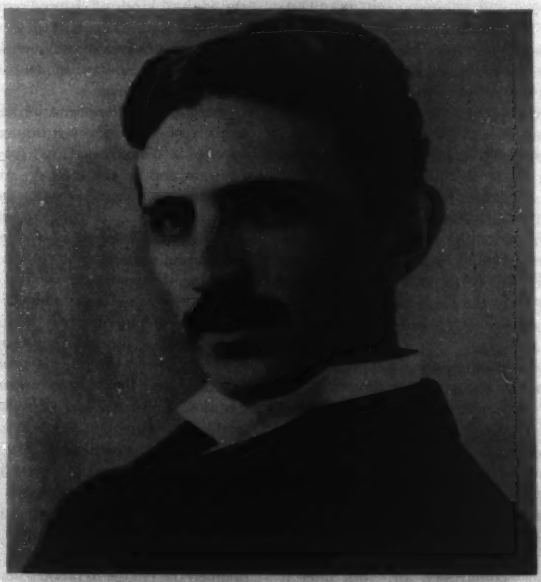
In May 1888 Tesla, in a paper before the American Institute of Electrical Engineers, announced his new system of a-c motors. In the new system polyphase currents produced in the motor a rotating magnetic field which induced currents in the closed motor secondary circuit, producing mechanical rotation. The rotative effect of alternating currents succeeding one another in time is analogous to two or three cylinders for producing continuous torque in an engine.

Westinghouse realized what this motor would mean for a-c service, and he acquired patent rights and Tesla's services. A serious situation was encountered. Commercial circuits were single-phase at a frequency of 133 cycles. Strenuous efforts to adapt the Tesla motor to this circuit were in vain. The little motor insisted in getting what it wanted, and the mountain came to Mahomet. Lower-frequency polyphase generators inflicted obsolescence on their predecessors in a thousand central stations—such was the potency of the Tesla motor.

The typical method of the '80's was the invention of a useful device such as an arc or incandescent lamp, or a railway motor, and the development of a "system" to operate it, which usually carried the name of the originator. In a decade there appeared a score of systems—technical or commercial—for each type of lighting and a dozen for street railways. The initiative lay with inventors and manufacturers; what they achieved was

accepted and used. But in 1890 came a challenge to solve an unprecedented problem.

In our milestone year, 1886, a charter was obtained for a great power development at Niagara Falls. By the initial Evershed plan many canals at right angles from the upper river were to supply separate wheel pits, each with a 500-horsepower turbine which would discharge its water into a tunnel system terminating at the foot of the falls. The project floundered until taken up by a New York group which entrusted its development to Edward Dean Adams. It was soon found that the cost of the proposed excavation of wheel pits and discharge tunnels for water wheels at points along $2\frac{1}{2}$ miles of river front for the prospective industrial city would be far too great. Economy called for location of the water wheels at one point, but the production of enormous power at one point called for transmission both for local industries and for greater distances. Commercial electrical methods for arc and incandescent lighting either by direct or single-phase alternating current or for street railways when few electric machines exceeded 100 horsepower—all were inadequate for the great project. A world-wide quest for methods and apparatus was conducted by the International Niagara Commission of experts from several countries, headed by Lord Kelvin.[9] It invited and received plans. A copy of the original record of the commission in five volumes—much in longhand—and 12 rolls of plans is in the Engineering Societies Library in New York. It shows the state of the art in 1890. The 17 projects from 20 representatives of six countries dealt with hydraulic equipment and with transmission. Of the best-presented plans for transmission, six were nonelectrical and four of these employed compressed air; of the six electrical plans, four used direct current. Typical of the latter was the connection of ten generators of 1,000 volts in series for 10,000-volt transmission to a similar arrangement of motors at Buffalo for driving generators for local distribution. Another plan proposed single phase, but "details were not fully described." The remaining plan by Professor George Forbes advocated a polyphase installation. He said: "It will be somewhat startling to many, as I confess it was at first to myself, to find as the result of a thorough and impartial examination of the problem, that the only practical solution for Buffalo and the best solution for the new industrial city which it is proposed to build near Niagara lies in the adoption of alternating-current generators and motors." He further stated: "The only non-synchronizing motor which has been developed in a practical form is the Tesla motor manufactured by the Westinghouse Electric Company and which I have myself put through various tests at their works at Pittsburgh. . . . The torque on starting is considerable . . . the largest I have tested was five horsepower . . . they have no commutator or even brushes or other collectors." He proposed generators of 500 horsepower (in a 50,000-horsepower station) and transformers of 100 horsepower, as he advocated only sizes already assured.



Nikola Tesla in 1894

The commission found no proposal acceptable; "no prize was awarded for system of distribution"; it looked favorably on electrical methods but was not convinced that alternating current was adequate. (Lord Kelvin persisted in his opposition to alternating current until he was proved wrong by its successful operation.)

That was the status of power transmission in 1890, when construction of the tunnel for 100,000 horsepower was under way.

The polyphase system gained fame through the 100-mile transmission from Lauffen to the Frankfort Exposi-

tion in 1891 in which a 30,000-volt circuit delivered power to a 100-horsepower three-phase motor designed by Dobrovolsky. The project had been proposed by C. E. L. Brown, eminent engineer and designer, to test transmission at high voltage by bare wires. He comments: "The three-phase current as applied at Frankfort is due to the labors of Mr. Tesla."[10]

The Niagara project was alluring and the Tesla method promising. The leading American electrical companies, Westinghouse, Thomson-Houston, and Edison General, did not present plans in 1890. Shortly afterward, the latter two united in the General Electric Company, which continued the development of polyphase apparatus already begun by Professor Thomson. Westinghouse prepared for Niagara, delegating general engineering leadership to L. B. Stillwell and generator design to B. G. Lamme. As a preliminary, the lighting of the Chicago World's Fair, 1893, was undertaken by polyphase current. In an exhibit a 500-horsepower induction motor (pinchhitting for a prime mover) drove a two-phase generator for supplying power to motors and lamps, and, via rotary converters and motor generators, to all types of d-c operation—from one source all services.[11]

The Niagara engineers had invited proposals and, when the two American companies indicated their readiness to proceed, visits were made to their works early in 1893 to inspect apparatus and discuss plans. Following successive presentations from both companies, a contract was awarded in October 1893 to the Westinghouse company for three 5,000-horsepower Tesla polyphase generators—several times larger than any predecessor. (Later seven more completed the 50,000-horsepower equipment of powerhouse 1. The plans designated powerhouse 2 as "compressed air," but later it was electrically equipped by the General Electric Company.)

The simultaneous development of the Niagara project and the Tesla system was a fortuitous coincidence. No adequate method of handling large power was available in 1890; but, while the hydraulic tunnel was under construction, the development of polyphase apparatus justified the official decision on May 6, 1893, five years and five days after the issuing of Tesla's patents, to use his system. The polyphase method brought success to the Niagara project; and reciprocally Niagara brought immediate prestige to the new electric system.

Power was delivered in August 1895 to the first customer, the Pittsburgh Reduction Company (now Aluminum Company of America) for producing aluminum by the Hall process, patented in the eventful year 1886. Thus the demonstration of alternating current by Stanley, the charter of the power company, and the beginning of aluminum, all occurred in the early months of 1886. Each evolved in its own devious way and then joined in less than a decade in initiating a new era in power, in electrical service, and in the light metal.

1896

In 1896, transmission from Niagara Falls to Buffalo, 22 miles, was inaugurated. Compare this gigantic and universal system capable of uniting many power sources in a superpower system, with the multiplicity of Lilliputian "systems" which previously supplied electrical service. As Mr. Adams aptly explained: Formerly the various kinds of current required by different kinds of lamps and motors were generated locally; by the Niagara-Tesla system only one kind of current is generated, to be transmitted to places of use and then changed to the desired form.

The Niagara demonstration of current for all purposes from large generators led immediately to similar power systems in New York City—for the elevated and street railways and for the subway; for steam-railway electrifications; and for the Edison systems, either by operating substations for converting alternating current to direct current or by changing completely to a-c service.[12]

The culminating year 1896 inaugurated two far-reaching developments for the extension of polyphase power, one commercial and the other engineering. By exchange of patent rights, the General Electric Company obtained license rights under the Tesla patents, later made impregnable by nearly a score of court decisions. Also the Parsons turbine, accompanied by its foremost engineer, was transplanted to America and enabled George Westinghouse to bring to fruition by a new method the ideal of his first patent, a "rotary steam engine." The acme of the reciprocating engine came in the early 1900's; a century's development produced the great engines that drove 5,000- to 7,500-kw alternators for New York's elevated and subway. But the rapidly growing steam turbine of different types soon doomed the engine to obsolescence; single units with the capacity of a score of the largest engines are now supplying power to the metropolis.[13] Single powerhouses now supply more power than all of the thousands of central stations and isolated plants of 1890.

At the turn of the century George S. Morison, eminent engineer, heralded manufactured power—engine power—as "The New Epoch"[14] in human progress, most significant event since the invention of the written alphabet marked the step from barbarism to civilization. He reviewed the contribution of power to the industrial revolution and the 19th century development, notably through mills and factories, locomotives and steamships. He foresaw its accelerating expansion through new types of prime movers and electrical methods of distribution and application. Further, he indicated the profound influence of these physical agencies on our ways of life.

Much of what was predicted 40 years ago has already come to pass—including conflict and war. In our present strenuous war effort, both in the making of materials and in industrial production the sine qua non is electric power, and more electric power. The output of central stations during the first year of the present war

was nearly ten times that of 25 years ago; it was greater than the immediately preceding year by 20 billion kilowatt-hours, the total output for the first year of World War I.[15]

Power and transportation have brought the nations of the world together as a unit. True, the development of physical facilities already moves faster than our ability to direct them to the social good. But the new epoch of power allows indefinite expansion in the progress of civilization and its contribution to the better life.

The coming of manufactured power marked the beginning of the new epoch in the progress of mankind. Electric power indefinitely amplifies the usefulness of mechanical power, through transmission and reincarnation in many motors, and by its production of light and heat and its contribution to chemical industry.

The evolution of electric power from the discovery of Faraday in 1831 to the initial great installation of the Tesla polyphase system in 1896 is "undoubtedly the most tremendous event in all engineering history."[16]

II—TESLA'S CONTRIBUTION TO HIGH FREQUENCY

L. P. WHEELER

DURING the early part of the last decade of the 19th century the attention of the whole scientific world was challenged by Nikola Tesla's public demonstrations of the effects of high-frequency alternating currents. It was then very early in the commercial age of electricity. The incandescent light had not yet become commonplace, electric traction was just being introduced, and the controversy over the relative advantages of the a-c and d-c systems was at its height. Tesla's own contribution to this controversy—one destined to be largely influential in the ultimate establishment of the low-frequency a-c system of distribution—was fresh in mind. The scientific world, stimulated by the brilliant investigations of Hertz in the latter part of the previous decade, was just beginning to adjust itself to the actuality of electrical effects at a distance without the use of wires and to the explanation of them as due to electromagnetic radiation. Further, it must be remembered that the beautiful and curious phenomena of conduction through low-pressure gases at that time had neither lost their novelty nor received any convincing explanation.

Thus the brilliant experimental demonstrations of Tesla in which the then customary limits both of frequency and voltage were far exceeded, coming at a time when the phenomena within those customary limits were not understood thoroughly, aroused extraordinary interest and stimulated research along several lines to a considerable extent. The lectures were literally as well as figuratively brilliant, as the effects of the high frequencies produced by his oscillation transformer were demonstrated chiefly by those luminous discharges in low-pressure gas tubes which may be regarded as giving the first impetus to the development of the modern methods of gas-discharge display lighting. By 1895 almost every physics laboratory in the country had built a "Tesla" coil, and much work immediately suggested by the lectures was under way. As far as the physicists were concerned, interest in such developments was, however, quite short-lived. This was due I think to two things:

1. There was a growing conviction (never shared completely by Tesla himself) that the distance effects were fundamentally attributable to electromagnetic radiation, and hence there was offered small hope of discovering any essential novelty. If there still remained some question as to the existence of some novel effect dependent on the very high voltages or frequencies or to their combination (a thesis maintained by Tesla himself throughout his life), the very general lack of existing equipment for dealing with the problems of insulation involved effectually discouraged any research in that direction.

2. That extraordinary series of discoveries (the electron, the X rays, radioactivity), which featured the second half of the 1890's and which almost overnight transformed physics from a striving for the next decimal place to an exciting exploration of new worlds, offered fields of research far more inviting and promising than that of high-frequency and high-voltage phenomena.

If, however, the lack of any effective follow-up of the Tesla phenomena on the part of physicists is understandable, it is more difficult to unravel the causes of the neglect of Tesla's procedure and devices in the commercial developments that followed, particularly those in the field of radio communication. One reason may lie in the fact that the industrial-research laboratory with equipment adequate to the problems involved was yet to be born. Another probably stemmed from Tesla's emphasis on the power rather than on the signal-transmission potentialities of his devices. The infant electric-power industry had too many difficulties on its hands in working out its destiny in the light of known principles and practices to spend much time or money or energy on totally untried projects or those involving little understood principles. Still another reason may be that the early successes of the Marconi and Slaby-Arco systems of wireless telegraphy without the use of the excessive voltages on which Tesla was so insistent, together with the (apparently) necessary connection

L. P. Wheeler, is chief, technical information division, engineering department, Federal Communications Commission, Washington, D. C.; and president (1943), Institute of Radio Engineers. Doctor Wheeler graduated from the Sheffield Scientific School of Yale University (bachelor of philosophy, 1894; doctor of philosophy, 1902); and was a member of its physics staff from graduation until 1926. Three of his former students, DeForest, Hogan, and Van Dyck, are past presidents of the Institute of Radio Engineers. He had an active part in the organization of instruction in the Signal Corps School for Officer Candidates at Yale in 1918 and of graduate instruction in communications for Army and Navy officers, at Yale, 1919–26. From 1926 to 1936 he was associated with the United States Naval Research Laboratory, first as physicist, then as consulting physicist concerned particularly with radio communication. From 1936 to the present he has been with the FCC. He is coauthor of the book "Principles Underlying Radio Communication." One of his student predecessors as president of the IRE, J. V. L. Hogan, says of him: "There are few men as well qualified to appraise Tesla's contributions to today's high-frequency techniques. Being well grounded in basic physics, and having been engaged in instruction, university and governmental research, and administration, he is able to view Tesla's work with a perspective not available to those more closely associated with industry."

between relatively *low* frequencies and long-distance transmission, created the impression that Tesla's techniques had nothing to offer the new art.

As to his own development of high-frequency applications, it is apparent from a study of his patent specifications that, while he was perfectly aware of the possibilities of his high-frequency devices for space communications and understood that signals for this purpose might be propagated as electromagnetic waves (see, for example, the patent specification 613,809, of 1898), nevertheless he seems to have assumed that such propagation would be effective only for relatively short distances. He apparently thought that world-wide communications would be effected either by some form of corpuscular or electronic convection in the stratosphere or through the earth by alteration of its charge. If his knowledge of electrical science outside of the domains of a-c circuits had been more adequate, or if he had followed up experimentally the communication potentialities of his earlier inventions, his great talents would probably have led to much more fertile results.

Whatever may have been the cause, it is nevertheless the fact that, in comparison with the effect of his development of the induction motor on the electric-power industry, Tesla's contributions to the high-frequency field have been remarkably sterile. Of the well-known earlier treatises on radio, that of Fleming refers to Tesla's high-frequency alternator and oscillation transformer, those of Pierce and Zenneck refer only to the oscillation transformer among the Tesla inventions, and in any text published since about 1915 there is rarely even the mention of his name. The young radio engineer of today may very well complete his formal education without ever having heard of Tesla, except in connection with the induction motor and the rotating field, or possibly as the "father" of the neon-tube lamp.

This seems somewhat unfortunate, for a perusal of his pertinent patent specifications would appear to indicate that, although not exploited effectively for communication purposes, there are at least three matters of prime importance to the radio art today on which Tesla's ideas were clearer than those of his contemporaries and on which he is entitled to either distinct priority or independent discovery. These are:

1. The idea of inductive coupling between the driving and the working circuits.

2. The importance of tuning both circuits, that is, the idea of an "oscillation transformer."

3. The idea of a capacitance loaded open secondary circuit.

It seems incontestable that all three of these fundamental ideas are clearly revealed in Tesla's patent specifications and lectures prior to 1894, although their application to communication purposes, while mentioned, is made incidental to the power-transmission objective. As none of these ideas appear in the specific literature of the radio art prior to the patent specifications of Marconi, Lodge, and F. Braun of the years 1897–1900, it would seem that Tesla's name is worthy of perpetuation as a pioneer of these ideas which have been so basic in the radio art down to the present. He never succeeded, however, in translating these ideas into an operative system for the transmission either of signals or power. A study of the group of patents issued to him at the turn of the century would seem to indicate that he did not realize the importance of the effect of antenna capacitance on the tuning of its circuit. Thus his proposed system was highly inefficient, if not inoperative. Hence, while he fairly may be considered a pioneer of the fundamental ideas already mentioned, he cannot be rated as the progenitor of their useful application, except as his work was a stimulus to others.

In addition to this major pioneering activity, Tesla made at least two contributions specifically in the communications field that are not generally known. The first is that embodied in the patent specification 613,809, dated November 8, 1898 (application July 1, 1898), entitled "Method of and apparatus for controlling mechanism of moving vessels or vehicles." This method of remote control operates on a succession of radio impulses whose incidence on a receiving antenna energizes through relays the battery-powered steering and propelling motors of the moving vessel and whose sequency and duration (at the will of the operator) determine the direction and amount of rudder rotation.

The inventor states that any method of producing the radio impulses (whether invented by himself or others) may be used, and that their propagation may be by means of Hertzian waves or by the mechanisms (previously mentioned) that he favored. Without passing on the operative merits of the proposed system, it would seem to the author that this invention deserves mention as the earliest radio remote-control system with which he is acquainted. A minor matter of interest in this specification is the very ingenious decohering device employed—one quite different from those in common use at the time and perhaps more certain in its action.

The second of these less known contributions is contained in patent specifications 685,957 and 685,958 of November 5, 1901 (application March 21, 1901), entitled "Apparatus for the utilization of radiant energy" and "Method of utilization of radiant energy," respectively. These describe a scheme which, in so far as it would be actually operative, depends on the changes in the charge on a capacitor produced by the incidence of the radiation (light) on an elevated-capacitance plate antenna connected to one of the capacitor terminals. It is thus seen to embody an application of the photoelectric effect discovered by Hertz in 1887, although Tesla seems to have been ignorant of that fact, and the explanation he offers is largely fallacious. It is not necessary to go into any of the details of these specifications. They are mentioned here only as illustrative of the experimental keenness which independently re-

discovered the Hertz effect and the ingenuity involved in finding a possible application for it. As far as the author is aware, this is the only suggestion of such an application on record.

After studying his patent specifications and the record of his public lectures, the author, in attempting to integrate and evaluate his impressions of Tesla and his work in the high-frequency field, has arrived at a mental picture of an immensely energetic personality possessing great skill in a-c techniques and great ingenuity in their practical utilization. There also emerges the image of a man unable to realize the limitations of his knowledge in other fields of science and the futility of mere ingenuity to overcome that handicap. These characteristics, combined with intense tenacity of purpose, resulted in the perversion of great talents into a largely unproductive direction. Nevertheless, his earlier accomplishments mentioned herein, together with the inspiration given to many through his public lectures,[17] would seem to justify a place in the history of radio engineering not so very far below that due to his accomplishments in the field of low-frequency alternating currents.

III—ADDENDA

TESLA'S EARLY PAPERS AND LECTURES

1888——A New System of Alternate-Current Motors and Transformers. *AIEE Transactions*, volume 5, 1888, page 305.

1891——Experiments With Alternate Currents of Very High Frequency and Their Application to Methods of Artificial Illumination (AIEE lecture at Columbia University). *AIEE Transactions*, volume 8, 1891, page 267.

1892——Experiments With Alternate Currents of High Potential and High Frequency. *Journal*, Institution of Electrical Engineers (London, England), 1892, page 51.

1893——Light and Other High-Frequency Phenomena. (Delivered twice.) (1) Franklin Institute, *Journal*, July 1893; (2) National Electric Light Association *Proceedings*, 1893.

BOOKS

1892——Experiments With Alternate Currents of High Potential and High Frequency (Tesla's London lecture). W. J. Johnston Company, New York, N. Y., 1892. 146 pages. Out of print.

1894——The Inventions, Researches, and Writings of Nikola Tesla; with special reference to his work in polyphase currents and high-potential lighting, **Thomas Commerford Martin** (past president AIEE). 493 pages. Out of print.

1932——Nikola Tesla und Sein Werk, **Dipl.-Ing. Slavko Boksan.** Copyright 1932 by Deutscher Verlag für Jund und Volk, Gesellshaft M Blf, Vienna I Burgring 9. Printed in Austria, Buchrrucherei Carl Gerold's Sohn, Vienna, VIII, Hamerling, platz 10. 344 pages. An encyclopaediac treatise.

1936——Nikola Tesla—Memorandum Book on the Occasion of his 80th Birthday, Edition de la Société pour la Fondation de l'Institut Nikola Tesla. 520 pages, Belgrade, 1936. The sponsoring foundation was established by the government for research. Sixty delegates from scientific institutions in 13 foreign countries joined the officers and members of the Yugoslav nation in conferences at Belgrade, May 26 to 31, 1936, followed by one-day celebrations at Zagreb (University) and Smiljane (Tesla's birthplace). Subsequent meetings were held in Paris, Vienna, and other European cities. Papers are printed in the seven languages in which they were written. Tables and reprints add to completeness. Tesla is credited (1936) with 113 United States patents: polyphase currents, 41; high-frequency currents and high voltage, 29; wireless systems, 18; others 25.

Among Anniversary Greetings in the "Memorandum Book" are the following:

Robert A. Millikan: "When I was a student in Columbia University I attended a downtown public lecture in New York at which you made one of the first demonstrations of your Tesla coil and its capabilities. Since then I have done no small fraction of my research work with the aid of the principles I learned that night."

Arthur H. Compton: "To men like yourself, who have learned first hand the secrets of nature and who have shown us how her laws may be applied in solving our everyday problems, we of the younger generation owe a debt that cannot be paid."

Lee De Forest: "No one so excited my youthful imagination, stimulated my inventive ambition, or served as an outstanding example of brilliant achievement in the field I was eager to enter, as did yourself. Your simple statement that you knew I could succeed, renewed my courage and gave me new faith in myself at a time when I was sorely tried."

Gano Dunn: "My contact as your assistant at the historic Columbia University high-frequency lecture and afterward has left an indelible impression and an inspiration which has influenced my life."

D. McFarlan Moore: "You fanned into a never-dying flame my latent interest in gaseous conduction."

E. F. Northrup: "When I began to give consideration to electrical methods for melting metal, my mind at once went back to those early demonstrations by you and the electric circuits which you described."

Tesla said in his London lecture that his aim was "to advance ideas which I am hopeful will serve as starting points for new departures." His success is attested by his followers.

REFERENCES

1. Niagara Power—History of The Niagara Falls Power Company, 1886–1918.—Evolution of its Central Power Station and Alternating-Current Power System (two volumes). **Edward Dean Adams** (John Fritz medalist). Privately printed for Niagara Falls Power Company, 1926, Page lx.

2. On an Electromagnetic Machine Constructed at the Cornell University Work Shop, **W. A. Anthony** (Past president AIEE). *American Journal of Science and Arts*, October 1876, page 251.

3. Some Reminiscences of Early Electric Lighting, **Charles F. Brush** (Past president, AIEE. Edison Medalist); The Pioneer Investigations on Dynamo Machines Fifty Years Ago, **Elihu Thomson** (Past president AIEE; Edison medalist). Professor Thomson refers to assistance by one of his "most promising pupils." E. W. Rice (Past president, AIEE. Edison Medalist). *Journal* of the Franklin Institute, volume 206, number 1231, July 1928.

4. *Electrical World*, May 25, 1889, page 293.

5. Report on the Exhibits at the Crystal Palace Electrical Exhibition, 1882, **Ensign Frank J. Sprague** (Past president AIEE. Edison medalist). Navy Department, Bureau of Navigation, Office of Naval Intelligence, 1884. Washington Government Printing Office (His British Association for the Advancement of Science paper is on page 448 of its 1882 *Proceedings*).

6. Patent 469,809; **William Stanley**—"I conceived the idea of so proportioning the converter as to secure a variation of the counterelectromotive force in the primary proportional to the current abstracted from the secondary." Object, parallel operation. Specification for "Induction Patent," sent to attorney November 26, 1885. Application for patent, August 15, 1888. In interference with Slattery patent 269,750, dated July 31, 1888. Patent issued March 1, 1892.

7. Patent 342,553; **George Westinghouse**—Transformer (*H* plate). Patent application made February 16, 1886; issued May 28, 1886. See Mechanical Development of Transformer by Westinghouse, **Charles F. Scott.** *Electrical Engineering*, December 1936, p. 1403. Contains description of the *H* plate, with drawing from patent. See also "Early Days of the Transformer," interview with Reginald Belfield, *Electrical World*, November 1, 1930, page 918.

8. Early History of A-C System in America. **C. C. Chesney, C. F. Scott.** *Electrical Engineering*, March 1936, page 228. In the introduction we find: "As part of the Institute's celebration of the 50th anniversary of the establishment of the a-c system in America . . . the early history has been prepared by two past presidents of the Institute, both of whom were actively identified with the early development of the system." (Westinghouse, Stanley, Chesney, and Scott are Edison medalists.)

9. Niagara Power (see reference 1). The International Niagara Commission, Volume I; organization, page 181; report on projects, page 401. "Niagara Power" describes the evolution of plans and apparatus culminating in the adoption of the Tesla polyphase system. It elaborates many of the condensed statements in the present paper.

10. *Electrical World*, November 7, 1891, page 346.

11. Exhibit of Polyphase System at the World's Fair, **Charles F. Scott.** *Proceedings*, International Electrical Congress, Chicago, 1893, page 417. Published by AIEE, 1894.

12. New York Electrical Handbook (one of 11 handbooks). A guide for foreign visitors to the International Electrical Congress, St. Louis, Mo. AIEE, 1904.

13. George Westinghouse Commemoration. A forum on the 90th Anniversary (1936) of his birth. American Society of Mechanical Engineers. 78 pages; also *Mechanical Engineering*, April 1937. Includes contributions on the steam turbine by Keller, Hodgkinson, and Smith, and alternating current by Berresford, Stillwell, and Beardsley.

14. The New Epoch as Developed by the Manufacture of Power, **George S. Morison.** Houghton Mifflin and Company, 1903. 134 pages. Out of print. A recast of his presidential address (American Society of Civil Engineers), 1895, and other addresses. Reviewed by Colonel Prout in *Electric Journal*, September 1906, page 494; also in his "A Life of George Westinghouse," page 325. The latter recounts the development of alternating current, including the World's Fair and Niagara installations.

15. *Electrical World*, January 23, 1943, page 90.

16. Edwin H. Armstrong (Edison Medalist 1942) in a letter to the author commenting on a draft of, "Tesla's Contribution to Electric Power."

17. See anniversary greetings, in "Nikola Tesla—Memorandum Book on the Occasion of His 80th Birthday," listed under "Books."

18. Nikola Tesla. For items on presentation of Edison Medal, see *Proceedings* AIEE, June 1917, and current issues of *Electrical World* and of *Western Electrician*. A biographical obituary item appears in *Electrical Engineering*, volume 62, February 1943, page 76.

INSTITUTE ACTIVITIES

The Coming Year's Task—*A Message From the President*

I am taking this opportunity to express my deep appreciation of the great honor which the members of this Institute have bestowed upon me in electing me their president.

I realize the difficulty which any individual must experience in following the footsteps of many of my illustrious predecessors, but I am buoyed up in the knowledge that the accomplishments of the Institute do not rest so heavily on the president nor are they so much the result of his activities as they are the outcome of the co-operative effort of the great body of the Institute membership, ever striving to increase the excellence of the performance of our organization.

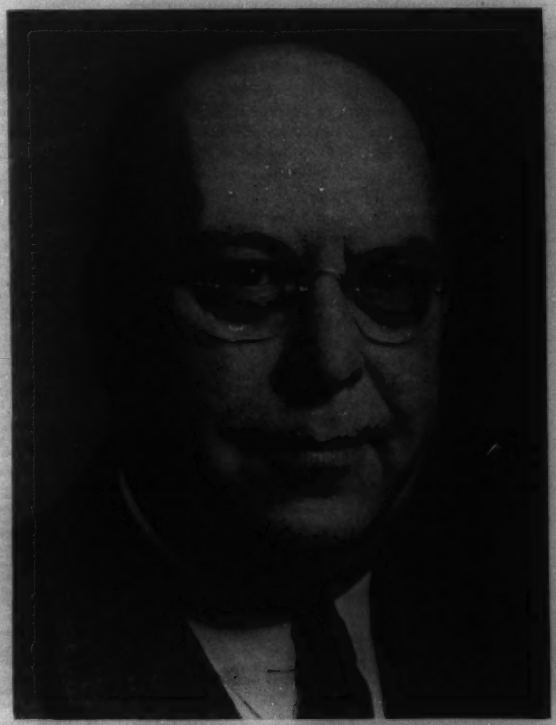
The Institute meetings and committee work have always constituted a forum for the exchange of ideas, and are more necessary today than ever, since the change to wartime economy has, of necessity, thrown many members into types of work with which they had no previous experience, and where they are frequently required to blaze pioneer trails. The ability to exchange ideas with those working in the same or an allied field results in a material speeding up of the effectiveness of all concerned.

Dependence should not be placed wholly on national meetings and national committees. The local Sections have a vital place in the program of helping the war effort, since they reach a much greater number of the Institute membership more frequently and are able by their efforts to provide effective help in their own areas.

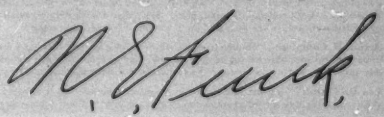
The technical staffs of industry are composed of men with different types of engineering background—electrical, mechanical, civil, metallurgical, chemical, and others—and a great many of the current problems involve more than one type of engineering, so that there exists a need for the ability of the members of different engineering societies to discuss jointly the problems which lie across the fields of their respective knowledge. This field of joint activity on the part of the national societies should also be carried into the work of the Sections which can arrange for joint meetings with other engineering societies to discuss problems to their mutual advantage.

Some of the members of the Institute and some of the local Sections have suggested the desirability of curtailing the Institute's activities for the duration of the war, which to me seems to be diametrically opposite to what should be done. Mechanization has made this an engineers' war more than any before, and if ever the Institute is to give maximum help to the nation, now is the time. This is not an academic conclusion, but is supported by the very practical evidence that the attendance and interest in technical meetings is continually increasing. At the recent national technical meeting in Cleveland, even the last day, and through sweltering heat, the audiences at the technical sessions were unusually large and greatly interested—an evidence of the desirability of this type of meeting.

The demands made upon our time because of present day conditions are a challenge to greater effort on our part to advance all phases of engineering activity.



Nevin E. Funk, President AIEE 1943–44



National Technical Meeting to Be Held in Salt Lake City, Utah, September 2–4

A program designed to aid the war effort and to meet the needs of western engineers has been arranged for the national technical meeting to be held in Salt Lake City, Utah, September 2–4. Meeting headquarters will be in the Hotel Utah. The program comprises five technical sessions and three conferences.

In accordance with AIEE wartime policies as adopted by the Board of Directors all programmed social activities have been omitted. However, Salt Lake City is the center of the scenic West and is known for its hospitality. Members and guests will be most welcome, and there will be opportunities for informal get-togethers, visits to nearby mountains and canyons, as well as swimming in Great Salt Lake. Those desiring to participate should inquire at the registration desk.

TRIP TO UTAH COPPER MINE

In conjunction with the conference on metallurgy and the conference symposium on lighting a special excursion has been arranged for 2 p.m., Saturday, September 4, to the mine, mills, and smelter of Utah Copper Company. As copper is

Tentative Technical Program

Wednesday, September 1

2:00 p.m. Advance Registration

Thursday, September 2

9:00 a.m. Registration

9:30 a.m. Opening of Meeting

9:45 a.m. Theory and Machinery

43-137. Turn-Ratio of the Capacitor Motor. **T. C. McFarland,** University of California

43-136. Some Measures of Electrical Brush Disintegration. **M. S. Coover, E. E. Jones,** Iowa State College

43-138. Temperature Limits and Measurements for Ratings of D-C Machines. **F. A. Compton, Jr.,** General Electric Company

43-144. Electronic Control of D-C Motors. **K. P. Puchlowski,** Westinghouse Electric and Manufacturing Company

2:00 p.m. Inspection of U. S. Bureau of Mines and University of Utah Laboratories

7:30 p.m. Conference on Metallurgy

CP.* Physical Aspects of Copper for Electrical Use. **P. H. Brace,** Westinghouse Electric and Manufacturing Company

CP.* Metallurgical Problems Arising From the Use of Copper in Electrical Equipment. **E. B. Parker,** General Electric Company

CP.* Metallurgy Production of Ferroalloys in Western States. **S. F. Ravitz,** U. S. Bureau of Mines

CP.* Production of Light Metals. **H. W. St. Clair,** U. S. Bureau of Mines

CP.* Quantitative Spectrographic Analysis. **Graham Marks**

7:30 p.m. Conference on Communication and Electronics

Address, "Electronics—A Tool for Industry." **R. H. Rogers,** General Electric Company

CP.* Use of Electronics in Metallurgical Research. **E. V. Potter**

Friday, September 3

9:30 a.m. Electrical Equipment for Military Aircraft

43-145. High-Voltage Ignition Cable Design for Aircraft. **H. H. Wermine,** Belden Manufacturing Company

● **ABSTRACTS of papers appear on pages 374–6 of this issue.**

● **PRICES and instructions for securing advance copies of these papers accompany the abstracts. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.**

43-140. Radio-Noise Elimination in All-Metal Aircraft. **Fred Foulon,** Douglas Aircraft Company

43-149. Parallel Operation of Airplane Alternators. **D. W. Exner,** Westinghouse Electric and Manufacturing Company

43-146. Aircraft Transformers—Small and Light. **O. Kiltie,** General Electric Company

CP.* Aeroplane Instruments. **R. L. Moeller,** General Electric Company

9:30 a.m. Selected Subjects

43-134. Effect of Frequency on Let-Go Currents. **C. F. Dalziel, Eric Ogden,** University of California; **C. E. Abbott,** Signal Corps

43-135. Effect of Wave Form on Let-Go Currents. **C. F. Dalziel,** University of California

43-139. The Automatic Welding-Machine Starter and Its Relation to Maximum Utilization of Power and Facilities. **N. E. Porter,** Permanente Metals Corporation

43-150-ACO.** A New Method of Measuring Contact Bounce. **P. H. Estes,** General Electric Company

12:00 m. Luncheon Conference for Students, Branch Counselors, and National Officers

2:00 p.m. Power Transmission

43-133. Lightning Surges Transferred From One Circuit to Another Through Transformers. **P. L. Bellaschi,** Westinghouse Electric and Manufacturing Company

43-151. The Effects of Mutual Induction Between Parallel Transmission Lines on Current Flow to Ground Faults. **J. I. Holbeck, M. J. Lantz,** Bonneville Power Administration

43-152. A New Simple Calculator of Load Flow in A-C Networks. **W. E. Enns,** Portland General Electric Company

43-141. Application of 720-Cycle Carrier to Power Distribution Circuits. **J. L. Woodworth,** General Electric Company

* CP: Conference paper; no advance copies are available; not intended for publication in *Transactions*.

2:00 p.m. Conference Symposium on Lighting

CP.* The Historical Episode of the Lighting of the Mormon Temple. **S. G. Hibben,** Westinghouse Electric and Manufacturing Company

CP.* Saving Materials in Industrial Lighting Systems. **F. C. Winkler, H. G. Barnett,** Westinghouse Electric and Manufacturing Comapny

CP.* Uses of Electricity and Light in the Metal and Coal Mines of Utah. **T. A. Robinson,** United States Smelting, Refining, and Mining Company

CP.* Ultraviolet Light Sources in Analyzing Ores. **H. T. Plumb,** Consulting Engineer

3:30 p.m. Conference on Effect of Altitude on Rating, Testing, and Operation of Electrical Apparatus

CP.* Review and Discussion of Present Standards. **P. L. Bellaschi,** Westinghouse Electric Company

CP.* Recent Testing

CP.* Operating Experience. **L. W. Robertson,** Public Service Company of Colorado

Saturday, September 4

9:30 a.m. Student Technical Session

9:30 a.m. Protective Devices

43-147. A New-Type Carrier Relay Protection. **E. M. Wood,** Hydro-Electric Power Commission of Ontario, **F. A. A. Bailey,** Canadian Marconi Company, **H. W. Haberl,** Montreal Light, Heat, and Power Consolidated

43-142. Dethermalizing Arc Quenchers. **L. F. Hunt,** Southern California Edison Company, Ltd., **F. H. Cole,** Cole Electric Company

43-148-ACO.** Development, Tests, and Operating Record of the Dethermalizer Arc Quencher. **F. H. Cole,** Cole Electric Company, **C. P. Garman,** Bureau of Power and Light, City of Los Angeles

43-143. A New One-Cycle Directional-Overcurrent Relay. **W. C. Morris,** General Electric Company

11:00 a.m. Conference on Mining—Introductory to Afternoon Excursion

CP.* Utah Copper Mining

CP.* Copper Smelting

CP.* Uses of Electricity in Copper Mining

2:00 p.m. Special Excursion to Utah Copper Mine, Mills, and Smelter

** ACO: Advance copies only available; not intended for publication in *Transactions*.

Table I. Hotel Rates

	Rooms With Bath	
	Single	Double
Hotel Utah (headquarters)		
South Temple and Main Streets	$3.30 –8.00	$4.40 –10.00
		6.60* –10.00*
	3.85**–5.50**	5.50** –7.50**
Newhouse Hotel		
Fourth South and Main Streets	2.20 –5.00	3.30 – 7.00
Temple Square Hotel		
West Temple and South Temple Streets	2.20 –3.50	3.30 – 6.00

*Twin beds. ** With shower bath.

Other hotels with rates from $1.65 to $3.50 per day are: Semloh Hotel, Second South and State Streets; New Grand Hotel, Fourth South and Main Streets; Monum Hotel, Fourth South and State Streets.

one of the most critical materials and the electrical industry was one of the largest users of copper, this trip should be most instructive. A first-hand knowledge of the industry, the physical properties of copper, and its uses, should aid the conservation of this critical material.

ADVANCE REGISTRATION

Members of Districts 8 and 9 and the nearby territory who receive the advance registration card and who expect to attend the meeting should fill in and mail the card promptly. A registration fee of two dollars will be charged all nonmembers except Enrolled Students and the immediate families of members.

HOTEL RESERVATIONS

To secure hotel accommodations reservations should be made as early as possible by writing directly to the hotel preferred. If assistance is desired, please write to C. A. Wolfrom, chairman, hotels committee, P. O. Box 899, Salt Lake City, 10, Utah.

COMMITTEE

Members of the national technical meeting committee making arrangements for the meeting are: A. L. Taylor, *general chairman;* L. D. Harris, *student activities;* A. C. Kelm, *finance;* J. A. McDonald, *publicity;* H. T. Plumb, *technical program;* C. A. Wolfrom, *hotels.*

Board of Directors Takes Action Opposing Kilgore–Patman Bills

Resolutions opposing the passage of the Kilgore–Patman bills were adopted by the board of directors of the AIEE at its meeting during the national technical meeting of the Institute at Cleveland, Ohio, June 21–25.

In brief, the Kilgore bill purposes the complete socialization of the scientific and technical resources of the nation, including all forms of property, methods, technical knowledge and data, and all personnel devoted to scientific and technical effort excepting physicians and dentists. Government control would be administered through a $200,000,000 bureau, and would extend beyond wartime into peacetime production. The Patman bill (H.R. 2100), its counterpart in the House of Representatives, is identical with the Kilgore bill in all important respects, and was considered jointly with it in the resolutions adopted by the board of directors.

These resolutions, prepared by the committee on research, June 22, and adopted by the board on June 24, 1943, are as follows:

1. *Whereas* the considered judgment of the Board of Directors of the AIEE, the national professional society of over 20,000 electrical engineers, is that the Kilgore–Patman bills S.702 and H.R. 2100 involve in their stated objectives research conducted by electrical engineers, and

2. *Whereas* the desirable objectives of the Kilgore–Patman bills are being attained by the Office of Scientific Research and Development, in co-operation with other agencies, and

3. *Whereas* the adoption of the Kilgore–Patman bills would tend to confuse rather than to clarify the present research programs, and

4. *Whereas* the research programs now in operation accomplish the desirable objectives of the Kilgore–Patman bills without the creation of an unnecessary governmental administrative organization, and

5. *Whereas* the concentration of great power in the hands of an appointed commission empowered to make restrictive regulations would tend to stifle rather than to promote creative research,

Be it resolved that:

1. The board of directors of the AIEE is strongly opposed to the passage of bills S.702 and H.R. 2100, and

2. These resolutions shall be published in *Electrical Engineering*, and the attention of Section officers shall be called to them,

3. Individual members of the Institute shall be urged to study the proposed bills to determine their effects upon electrical-engineering research, and

4. When invited by proper authority, the President of the AIEE is authorized to appear in person or by representative to explain further the board's position regarding these bills.

WHAT THE KILGORE BILL PROPOSES

Basic to the development of the senatorial bill is the establishment of a national scientific and technical office to integrate, initiate, and execute the purpose of the act as outlined in the declaration of policy.

This office, to be known as the Office of Scientific and Technical Mobilization, would be headed by an administrator appointed by the President with the advice and consent of Congress. A National Scientific and Technical Board and a National Scientific and Technical Committee would be set up by the bill, as well as a committee charged with maintaining the secrecy or restricted character of any information coming into the possession of the office.

The board's membership would be appointed by the President, and would consist of one representative each of labor, industry, agriculture, and the consuming public, and two additional members at large who would be scientists or technicians. The administrator would serve as chairman, and board members would perform such duties under the direction and control of the administrator as he might deem requisite to the successful operation of the office. The committee, an advisory group, would include the board members, four additional representatives of the consuming public, three additional scientists or technologists, six additional members each representing labor and management in the major fields of production and service, and one representative each of certain federal agencies designated by the President.

Automatically transferred, under the provisions of the bill, to the Office of Scientific and Technical Mobilization

An inspection trip is scheduled to be held September 1, during the AIEE national technical meeting at Salt Lake City, Utah, to this experiment station which houses the headquarters of the metallurgical division of the United States Bureau of Mines. Since most of the Bureau's stations primarily devoted to metallurgy lie west of the Mississippi River, division headquarters were moved to Salt Lake City when this station was completed in 1939

would be all the powers and personnel of the National Roster of Scientific and Specialized Personnel of the War Manpower Commission, together with its records, equipment, and all its unexpended balances of appropriations.

Through its administrator, board members, and other agents, the office would be empowered:

1. To maintain a census of scientific and technical facilities, requirements, and personnel in the United States and its possessions, and to provide archives for all scientific and technical material coming into government possession.

2. To develop comprehensive national programs for the maximum use of science and technology, in the national interest, in periods of peace and war.

3. To mobilize for the prosecution of the war all scientific and technical facilities and personnel.

4. To facilitate, after the war, the transition of national economy from the tasks of war to peacetime enterprise.

5. To formulate and promote projects and programs for the development and use of scientific and technical facilities and personnel and, when necessary, to initiate and carry out such projects.

6. To facilitate access to scientific and technical information, and to aid and encourage the writing and publication thereof.

7. To foster, develop, and finance scientific and technical methods, inventions, training and data to promote their application in the public welfare, and to promote and provide training and participation in science and in its application.

8. To help smaller businesses by making the benefits of scientific advancement available to them.

9. To discover and develop substitutes for strategic and critical materials, and to promote the most beneficial use of agricultural, mineral, and other natural resources.

10. To standardize, when in the public interest, scientific and technical designs, practices, and specifications.

11. To advise the President and Congress on scientific and technical matters.

12. To foster domestic and international co-operation in scientific discovery and technology.

13. To provide for occupational deferment of scientific and technical personnel when such personnel can be used best on the domestic front.

14. To establish a system of merit awards for outstanding scientific and technical contributions.

15. To initiate employment programs for voluntary participation of scientific and technical personnel in the war effort.

Some of the powers and duties implicit in the office could be exercised only when the nation is in an existing state of war or in a state of national emergency such as was declared on May 27, 1941. Such a power would be the authority to requisition, for suitable compensation, any scientific or technical facility or right, other than a patent itself, determined necessary for the defense of the United States or for the prosecution of the war. Another would be the authority of the administrator, subject to the chairman of the War Manpower Commission, to prescribe and promulgate appropriate regulations and procedures for the training, classification, and employment of all scientific and technical personnel until six months after the termination of war.

As regards patents, the office would be vested with the exclusive right to use, or to license others to use, any invention, discovery, patent, or patent right if the United States has contributed in any way to its development since May 27, 1941, or will contribute to it hereafter, or if, after the passage of the bill, it becomes to any extent government property. The office also would be empowered to acquire patents and patent rights and to authorize their use on a nonexclusive basis.

Among special privileges allocated to the administrator would be the power to create or to organize corporations as instrumentalities for the more effective exercise of his own duties or those of the office. In such an instance, he might make loans to, or purchase the capital stock of, any such corporation for any purpose within the powers of the corporation, provided the stock is owned only by the office.

Future AIEE Meetings

National Technical Meeting
Salt Lake City, Utah, September 2–4, 1943

Southern District Meeting
Roanoke, Va., November 16–18, 1943

National Technical Meeting
New York, N. Y., January 24–28, 1944

Ten Wartime Guides Presented at Summer National Technical Meeting

Wartime guides covering the application and operation of ten different types of electrical apparatus were presented at the AIEE national technical meeting, Cleveland, Ohio, June 21–25, 1943. As announced previously (*EE, June '43, p. 258*), the underlying theme of the guides is the conservation of materials through increased loading of equipment when conditions permit. Inter-American relationships also figured prominently at the meeting, being the subject of the general session at which two feature addresses were delivered, and of a conference at which informal talks were given on various aspects of the question, "How Can the Institute Render Greater Service to Its Latin-American Members?"

A total of 12 technical sessions and 10 technical conferences comprised the technical program of the meeting, as announced previously. This represents an enlargement compared with the 1942 summer meeting, in order to allow scheduling of as many subjects as possible related to war problems. There was standing room only at the two sessions on electrical equipment for military aircraft, demonstrating the intense interest in this subject at the present time. These two sessions were held Friday, the final day of the meeting, and many came to the meeting solely to attend those sessions. One conference was devoted to discussion of the engineer's interest in city planning, continuing the series of conferences on the general subject of civic affairs which have been held during recent national and District technical meetings. Two inspection trips, both related to conferences, were held; one to Nela Park, lighting division of the General Electric Company, where a conference on wartime lighting was held; and the other to the plant of the Ohio Crankshaft Company, where induction heating of metal parts was demonstrated. As all formal technical papers and approved discussions presented at the technical sessions will be published in the *Transactions*, no news reports of those sessions are included here. Brief reports on the conferences are presented in separate items, as they have become available.

Included on the meeting program were the usual items of the annual business meeting of the Institute and the annual conference of officers, delegates, and members. The latter comprised a combined morning session and two parallel afternoon "clinics" on the operation and management of larger and smaller AIEE Sections, respectively. Reports of these events may be found in separate items. There was one joint affair on the program, a dinner conference under cosponsorship of the AIEE and the Cleveland section of the Institute of Radio Engineers. An address, "Frequency Modulation Versus Amplitude Modulation at High Frequencies," was delivered by Raymond Guy, radio facilities engineer, National Broadcasting Company, New York, N. Y. F. C. Everett presided.

Meetings of several AIEE committees and subcommittees were held during the meeting week, as was also the regular meeting of the board of directors. At the latter, resolutions were adopted against passage of the Kilgore and Patman bills now pending in Congress (see separate item).

A total of 1,170 members and guests registered at the meeting, as compared with 1,179 at the 1942 summer meeting. Registration details are given in the accompanying tabulation. The meeting as a whole reflected the results of much careful planning and hard work on the part of the meeting committee and the various subcommittees handling the details.

COMMITTEES

The committee responsible for this year's summer meeting consisted of:

Wm. E. Wickenden, *chairman;* B. W. David, *secretary-treasurer;* G. R. Canning, *vice-chairman;* D Romadanoff, *secretary;* L. T. Blaisdell, P. L. Hoover, A. J. Kres, Mrs. A. M. MacCutcheon, D. E. Moat, E. A. Rossrucker, J. C. Strasbourger, and J. J. Tesar.

The general committee was assisted by the following subcommittees:

Finance: L. T. Blaisdell, *chairman;* B. W. David, *secretary-treasurer;* F. E. Cooper, H. J. Dible, Ward Harrison, W. C. Kalb, Wm. H. LaMond, A. M. MacCutcheon, and H. L. Wilcox.

Hotel: J. C. Strasbourger, *chairman;* L. C. Brewster, J. Jenkins, R. W. Loehr, C. C. McCall, and R. L. Oetting.

Meetings and Papers: P. L. Hoover, *chairman*; W. C. Kalb, F. H. Knapp, J. D. Leitch, S. E. Leonard, and R. W. Loehr.

Publicity: E. A. Rowrucker, *chairman*; R. L. Oetting and C. F. Paulus.

Registration and Information: A. J. Kres, *chairman*; O. F. Ankenbrandt, A. F. Kunz, L. A. Neureither, W. R. Uffelman, and L. P. Winsor.

Transportation and Trips: J. J. Tesar, *chairman*; H. C. Bingham, A. D. Fishel, C. E. Ganther, F. W. Jackson, R. C. Putnam, G. B. Schneeberger, and J. L. Vergilio.

Annual AIEE Business Meeting

The annual business meeting of the AIEE held June 22 during the recent national technical meeting in Cleveland, Ohio, was the 60th annual meeting of the Institute, if we include in that count the organization meeting on May 13, 1884, declared President Harold S. Osborne, who presided. "During the past year the Institute has cut its activities very closely to the war pattern," he said. "I think that the very high level of activity under that war pattern," he continued, "has shown what a large amount the Institute has to contribute to the war effort." Following his opening remarks, President Osborne introduced Doctor William E. Wickenden (F '39), chairman of the general meeting committee and president of Case School of Applied Science, who extended the official welcome.

An unannounced item of the meeting was the introduction of Colonel John Millis (M '85), senior surviving member of the AIEE. He was among the first group of members elected (July 7, 1884) to the Institute after its organization. He is now retired and resides in Cleveland. After his introduction, Colonel Millis stepped to the platform and made a few appropriate remarks.

Included on the agenda were the annual report of the board of directors, the annual treasurer's report, report on election of officers (*EE, July '43, p. 313*), presentation of President's badge to President-Elect Nevin E. Funk, and the report of the committee on award of Institute prizes. Other features included an address on community planning, and presentation of the 1942 Lamme Medal to Joseph Slepian (A '17, F '27), associate director of research, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. Excerpts from the former are given in succeeding paragraphs; essential substance of the medal presentation addresses is scheduled for publication in a later issue. The meeting concluded with the annual presidential address on the subject "Planning for Things to Come," full text of which appears elsewhere in this issue.

ANNUAL DIRECTOR'S REPORT

The annual report of the AIEE board of directors for the fiscal year ending April 30, 1943, was presented in abstract by National Secretary H. H. Henline (F '43). He called attention to the wartime policies adopted by the board last year and to the heavy emphasis, at the 1942–43 National and District technical meetings, on technical material contributing toward the war effort. Mr. Henline discussed also the activities of the various Institute committees and the manner in which their work is influenced by wartime demands.

The Sections held some 600 meetings during the year as compared with some 650 during the previous year. While this total represents a drop, it is a higher figure than for any year prior to 1937. Two new Sections were formed during the year, one in Montreal, Que., and one in Dayton, Ohio; the latter was first organized as a subsection of the Cincinnati Section to which it had been attached for many years. One new student Branch was organized, at Vanderbilt University, Nashville, Tenn., bringing the total number to 125.

Recent Summer-Meeting Attendance

1943	Cleveland, Ohio	(2)	1,179
1942	Chicago, Ill.	*(5)	1,173
1941	Toronto, Ont., Can.	(10)	1,204
1940	Swampscott, Mass.	(1)	1,010
1939	San Francisco, Calif.	(8)	945
1938	Washington, D. C.	(2)	827
1937	Milwaukee, Wis.	(5)	1,065
1936	Pasadena, Calif.	(8)	714
1935	Ithaca, N. Y.	(1)	901
1934	Hot Springs, Va.	(4)	350

* District numbers in parentheses.

A net gain of 1,217 members was reported by the membership committee, which is the largest for any year except one —1920–21. At the close of the fiscal year, the membership stood at 20,161 and by June 1 it had reached 20,298. Mr. Henline also called attention to other features of the report, including the financial report by the Institute's auditors. (As announced in the July issue, the full report is not being published in *Electrical Engineering* this year, but copies may be obtained by AIEE members upon request from AIEE headquarters.)

TREASURER'S REPORT

Total receipts of $391,948.41 for the year 1942–43, as compared with $344,910.88 for the preceding year, were reported by National Treasurer W. I. Slichter (F '12) in his summary report. Total expenditures for the two years were, respectively, $354,377.70 and $320,748.82. Mr. Slichter reported the total value of all reserve funds as $328,251.31, compared with $289,007.84 for the previous year. The book value of all securities he reported as $278,398.33 for the year just ended, compared with $225,220.33 for 1941–42; market value of all securities for the two years was given, respectively, as $275,195.03 and $203,652.82.

PAPER PRIZES PRESENTED

P. L. Alger (F '30), chairman of the committee on award of Institute prizes, gave the report of that committee, after which prizes were presented to authors of the best 1942 national papers in various classifications. The recipients of these prizes were announced in the July issue (*page 314*) together with those awarded prizes by six AIEE Districts.

TOKEN TO TREASURER SLICHTER

Another unannounced item on the program was the presentation of a token of appreciation, in the form of an engraved certificate, to National Treasurer W. I. Slichter in recognition of his long and active service in the Institute. The occasion recognized the 25th anniversary of his election as an officer of the AIEE. In 1918 he was elected a manager; subsequently he served as vice-president (1922–24), and from 1930 to date he has served continuously as national treasurer. "Throughout that time he has served the Institute very actively," said President Osborne. "He has been on 34 committees, and . . . has a record of contribution to the Institute which is unparalleled in our organization and probably in any other. He not only has been on these committees but has served the Institute as representative on many boards." President Osborne then introduced Comfort A. Adams, who was AIEE president in 1918 when Professor Slichter was first elected an officer of the Institute and who delivered the following tribute to Professor Slichter.

"My duty is a very pleasant one. As we grow older, our perspective is apt to clarify and our sense of values to change. Thus, this simple and delightful act of honoring a beloved colleague becomes to me a symbol of national and international significance.

"Many of us have seen the world contract to a fraction of its size since we were children. In fact, our own profession, of which this Institute is the largest and most influential organized representative, has participated largely in that contraction, and we are apt to be very proud of that participation. However, one of the indirect results is by far the greatest war in human history. To me, at least, the lesson seems obvious, namely, that if anything worthy of the name of civilization is to survive, we must learn how to co-operate in a friendly and even generous fashion, rather than to fight blindly for material wealth without realizing the appalling price that we and many others must pay.

"This Institute is from one point of view a little world in itself, a world of friendly

Analysis of Registration at 1943 Summer National Technical Meeting

Classification	Districts 1	2	3	4	5	6	7	8	9	10	Total
Members	105	404	82	21	126	4	25	8	7	23	805
Men guests	18	207	8	2	34		3	1		4	277
Women guests	4	53	9	3	15		2	1		1	88
Totals	127	664	99	26	175	4	30	10	7	28	1,170

and nonprofit co-operation. It was organized to do an important job, to render an important service to its members and to society at large, but most of that service is not paid for in dollars. Fortunately, there are other types of reward which to many of us cannot be measured in dollars. In fact, most of the enduring satisfactions of life, including the most worth-while form of happiness, are of that type. Those who have come to a working realization of these facts are to be counted as fortunate, since the real reward is automatic.

"Thus, our Institute is a kind of training ground for co-operation or democracy, where we learn of the deep satisfaction of service and come to realize that our own welfare and happiness are largely dependent upon that of a host of others with the same goal in view.

"Although in these days some are inclined to scorn what they refer to as the 'old-fashioned code', it is still a fact that the satisfaction that comes from serving others, of even society at large, is immeasurably greater than that which comes from being on the receiving end in the material sense.

"In presenting this token we are honoring one of our most faithful servants—I like that word.

"As I look back over nearly 50 years of membership in our Institute, I recall no other who has given so much of his own time and so much valuable service over such a long, uninterrupted period. When I first knew Walter Slichter, he was a brilliant young designing engineer. Later, he became one of our foremost teachers of electrical engineering, and for the past quarter century, his continuously devoted service to our Institute has undoubtedly been a real factor in making it the greatest organization of its kind in the world.

"In addition, he has so endeared himself to every member of the Institute with whom he has come into intimate contact that we are all proud to call him 'friend.'

"The deeper my convictions, the more difficult I find it to do justice to them in words. What I wish most to emphasize is not the obvious material service, but rather the spirit of that service, which cannot be evaluated in words, but is instinctively felt by everyone who comes under its spell—the unostentatious spirit of cheerful service, of kindly human sympathy and fair play, which is more enduring and far-reaching than most of us realize. It is this spirit which gives us a spark of faith that those millions who are now paying the price of ignorance and greed may not suffer and die in vain."

After Doctor Adams presented the certificate, Treasurer Slichter responded briefly with appropriate remarks, expressing his deep appreciation of the token and his great satisfaction in having been of service to the Institute.

ADDRESS ON COMMUNITY PLANNING

One of the special events at the annual business meeting was an address on "The Fact Basis for Community Planning," by Howard Whipple Green, director of real property inventory of the City of Cleveland. In introducing his address, Mr. Green said that he would talk more about community facts than community planning These facts, he said, may be of several types, and he discussed four.

1. Those relating to the entire community—the population, how many people live here, how old are they, what is their sex and nativity, their race, their educational status, occupation, how many wage earners are employed in industries, the bank deposits' total, how many families have telephones, electric refrigeration, radios, how many of them are still in operation.

2. Those of historical nature, which show the trends over the years: How has population increased, or is it decreasing and to what extent? How does the value of manufactured products change? What is the rate of increase of kilowatt-hours of electricity sold? What is the change in the number of business telephones, the increase of service provided by public utilities, public transportation?

3. The general unrelated class including climate and rainfall, mortality rates, golf courses, parks, churches, schools, children, teachers, cultural institutions. In other words, what kind of place is it in which to live and to work?

4. Those relating to all of the three preceding classes, but which relate those items on a geographical basis.

Mr. Green devoted the principal portion of his address to the fourth class of facts mentioned. Oftentimes, he said, facts for the country as a whole are broken down into states or regions, cities or industrial areas, and into metropolitan districts or combinations of other areas. Likewise, the approach to a study of even so small a unit as the community is facilitated by dividing it into wards, boroughs, or precincts, health districts, school districts, or police precincts, or some other specially designated area. His recommendation for such a unit was the census tract.

The idea of considering communities in the light of census tracts, or geographically constant areas of approximately a half-million population, was first conceived by Doctor Walter Laidlaw of The Greater New York Federation of Churches, Mr. Green stated. Discovering that the only statistics published by the United States Bureau of Census available for the study of communities and neighborhoods were on a borough basis, and that each borough was larger than most entire cities in the United States, he proposed the idea of census tracts or sanitary areas. They were adopted by the Bureau of Census in 1910 for cities having a population of half a million or over.

Very little was done with these areas outside of New York City, however, Mr. Green continued, until 1926 or 1927, when Chicago and Cleveland at the same time became interested in the small areas. At the time of the 1930 census, 18 cities in the United States were laid out by census tracts, and by 1940, the Bureau of Census had approved 60 cities, and had assumed the responsibility of publishing at its own expense the data of these cities. Today, Mr. Green pointed out, such data are available in every city of the United States of over a quarter-million population and in some cities under a quarter of a million.

The chief advantage of using the census tract rather than wards, precincts, school districts, or other units, in studying a community is that the boundaries of the census tract are constant while those of the other areas change almost constantly. Theoretically, by the state law in Ohio, the wards change every ten years. As soon as the population becomes available by wards, there is an entirely new group of wards. The population that is served by a school district changes as new school buildings are built which cannot be moved or shifted around, so that census tracts are the only areas that maintain fixed boundaries.

The real property inventory of Cleveland has made use of census tracts in its survey of the community conducted annually since 1932. Each October, all the dwellings and nonresidential buildings in the community are visited to determine occupancy and vacancies, and to estimate the family count. New construction by year is determined by census tract, and sublotting activity has been studied by census tract yearly since 1802, when the first sites in Cleveland were laid out in real estate development.

The remainder of Mr. Green's address consisted of slides depicting various statistics for Cleveland by census tracts.

Sections Problems Dominate Conferences of Officers, Delegates, and Members

Reports of Sections activities during the past year and informal discussions of Sections' operating problems comprised the major portion of the conferences of officers, delegates, and members, held during the recent AIEE national technical meeting at Cleveland, Ohio. A series of scheduled talks and prepared reports occupied the attention of those at the Monday morning conference, which was the opening session of the meeting. In the afternoon two so-called Sections clinics were held, one for the larger Sections and the other for the smaller ones. Those from Sections having a membership of over 300 met in one group and less than 200 in the other group. Those from Sections having between 200 and 300 members had the choice of attending either.

Talks by President Harold S. Osborne, President-Elect Nevin E. Funk, and National Secretary H. H. Henline, were included on the morning program, in addition to a comprehensive report on Section activities during the past year with supplementary reports on some of the special projects undertaken by the Sections committee. An informal address entitled "I Am an American" added flavor to the conference in keeping with the times.

PRESIDENT'S IMPRESSIONS FROM VISITS TO SECTIONS

President Osborne reported that during the past eight months he had visited some

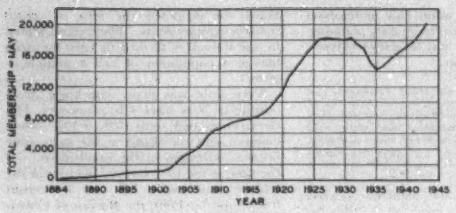


Figure 1. AIEE Membership

30 AIEE Sections and that he had been particularly impressed with the vitality of the work of the Sections and with the fact that they form what might be called both the heart and the backbone of Institute activities. About half of the meetings held during the past year have been closely related to the war effort, which includes about 25 per cent on conservation of materials and about 7 per cent featuring talks by men in the armed forces. "It is quite clear," he said, "that the Sections have been conscious of the war and that they have been adapting themselves well to the new conditions." He cited the formation of subsections and of an aircraft division in one of the Sections as illustrations.

One of the things that President Osborne reported as having impressed him most was the hearty co-operation between the Sections and other engineering groups, which he characterized as a very healthy sign. About a quarter of the meetings during the past year were joint meetings with one or more other engineering groups. He urged the Sections to consider during the coming year whether this percentage should not be increased because during wartime many subjects that will be discussed obviously will be of interest to other engineering groups. "Another phase of this co-operation," Doctor Osborne continued, "is the development of additional local engineering societies or clubs which represent all the engineers." He termed this one of the most effective ways in which engineers can achieve a greater participation in civic affairs.

DOCTOR FUNK SPEAKS BRIEFLY

At the conclusion of his talk, President Osborne introduced Doctor Nevin E. Funk, whose election as AIEE president for the ensuing year was announced the following day.

Emphasizing the value of experience in Sections work to those on national committees, Doctor Funk declared: "Like any democratic body, the Institute to function efficiently depends essentially on a very high degree of co-operation and the development of an understanding of the humanities in dealing with your fellow men. I think the best place to develop that is in the local Section meetings." Characterizing the majority of engineers as poor speakers, he also declared that the Sections provide very good opportunities for training in public speaking.

"AIEE BULLETIN"

Issuance of the first number of a new quarterly "AIEE Bulletin" for members in the armed services and the merchant marine was announced by F. A. Lewis, acting editor. He briefly described the content of the first issue and indicated the general direction of hoped-for development in succeeding issues (see announcement elsewhere in this issue).

"I AM AN AMERICAN"

A feature of the conference not directly related to the main business of the meeting but appropriate to the times was the talk entitled "I Am an American" by A. Boyajian (F '26), General Electric Company, Pittsfield, Mass. Constituting an extension of an earlier talk on the same subject (*EE, Dec. '42, p. 614*), Mr. Boyajian, himself an immigrant, said that while many a native-born American is proud of having a pilgrim in his family tree, many an immigrant American is proud of being a pilgrim himself. By a series of anecdotes he illustrated what Americanism means to these people, many of whom came to America to escape the tyranny of their mother countries.

INSTITUTE MEMBERSHIP AND FINANCES

Mr. Henline reported graphically on the status of the Institute's membership and its finances. His first slide, Figure 1, showed AIEE membership statistics on an annual basis from its organization in 1884 with 71 charter members to its April 30, 1943, total of 20,161.

As originally established, the AIEE had annual national meetings in various places, but little was done in the first decade and a half to expand the Institute throughout the United States. Efforts to establish regular and periodic local meetings as well as the annual national convention began to succeed about 1902, under the presidency of Doctor Charles F. Scott, as an ever-increasing membership pointed to their desirability. Doctor Scott also initiated arrangements for the local meetings of students in leading engineering schools throughout the country as well as for those older members already established in the profession.

By 1905, membership in the AIEE had topped that of any of the other three Founder Societies, a position it held until 1915. During the depression years, many members remained on the roll in an inactive status, by a special action of the Board of Directors. However, membership and finances slumped alarmingly, the former backsliding 22 and the latter 43 per cent. Our ranking position was forfeited but was regained and has been maintained since 1937.

On his second slide, Figure 2, Mr. Henline employed three curves, representing, respectively, receipts from advertisements and dues, and total receipts, per year. Revenue from advertising, first undertaken in 1922, rose gradually to the peak total of $85,000 per year, and then dropped abruptly during the depression. Dues maintained its level on a percentage basis much better than did advertising. Both are advancing now toward new peaks.

SECTIONS COMMITTEE REPORT

Chairman E. T. Mahood, reporting for the Sections committee, reviewed the manner in which the sixfold program adopted by the committee after its appointment last August had been executed.

One of the major determinations of the committee was the shaping of Section programs to the general pattern of the war effort. Two among the wide variety of programs on war subjects were specifically cited. The first of these was the program on the conservation of critical materials promoted largely by President Osborne and used by about 75 per cent of the Sections. Second, were the clinics relating to methods of improving production of war materials, sponsored by the War Production Board in many large manufacturing centers with the joint co-operation of the AIEE and other technical and engineering societies. The promotion of joint meetings to save time on the part of the engineers in the preparation of papers and in traveling was mentioned not only as contributing to the war effort, but also as a movement that may have lasting value to the engineering profession.

A second major aim was the development of South American Sections. Mr. Mahood reported the formation of a subcommittee, under the chairmanship of O. C. Brill,

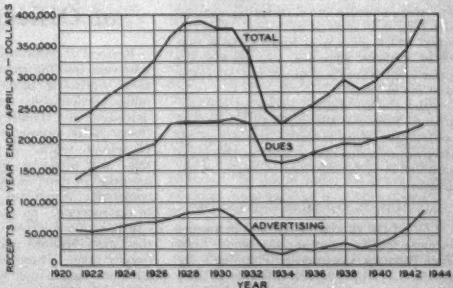


Figure 2. AIEE receipts

who has reported separately, to investigate and follow through proposals toward that end. An accompanying tabulation illustrates how widespread the AIEE membership is, and details the number of members in each of the various countries of South America. He quoted Mr. Brill as reporting sentiment in favor of forming Sections in Brazil, with 45 members, and Columbia, with 15 members. Others that might have possibilities are Argentina, with 29, Cuba, with 26, Puerto Rico, with 33, Chile, with 18, and Venezuela, with 15. Places like the Canal Zone, with 42, Alaska, with 13, Hawaii, with 38, along with Europe and Asia, are now so busy that the establishment of Sections will have to be deferred for a while.

Providing a vice-president especially to look after the interests of these 1,268 members (about as many as in the average District in the United States and Canada), to keep in touch with developments and possibilities in these countries, and to act as advisor to the Board of Directors on the special problems involved in financing and operating Sections in these countries, should be considered the logical preparation for extension of the Institute's help and influence in this direction, Mr. Mahood stated.

He then analyzed some of the financial aspects of the problem, his figures showing that the operation of foreign Sections would be feasible from this point of view if no travel allowance is made for delegates to attend the summer meeting.

At this stage in their development, plans for foreign Sections are merely recommendations of the Sections committee, Mr. Mahood stated, and are now being referred to the board of directors for consideration.

Another consideration of the committee was the assignment of territory to North American Sections. During the past year these changes have occurred:

1. Unassigned Nevada was divided between Utah, Los Angeles, and San Francisco Sections.

2. Unassigned Manitoba and Alberta Provinces were added to the territory of the former Saskatchewan Section, and the name changed to Mid-Western Canada Section.

3. A new Section was established at Montreal, Canada, with the Province of Quebec and part of Ontario as its territory and with a membership of 175.

4. A new Section was established at Dayton, Ohio, with about 95 members.

Only 51 members in the United States and Canada remain without Section affiliation, about half of these in Arkansas and half in the Maritime Provinces of Canada.

Foreign Membership, November 1, 1942

Mexico (1 Section)	63	Bolivia	8
Cuba	26	Brazil	45
Puerto Rico	33	British Guiana	3
Other West Indies	18	Chile	18
Bermuda	5	Colombia	15
Central America	18	Ecuador	2
Canal Zone	42	Paraguay	1
Alaska	13	Peru	7
Hawaii	38	Uraguay	1
Africa	52	Venezuela	15
Asia	290		
Australasia	112	Total South America	144
Europe	401	Grand total	1,268
Argentina	29		

Mr. Mahood proceeded with some interesting statistics on Sections, but was of the opinion that perhaps not many generalizations could be deduced from them since Sections and Districts must fit existing conditions within their limits. He suggested, however, as a Section objective of universal application the motto:

"To have every qualified person in its territory actively at work to promote the Institute's objective."

A fourth aim of the committee was the development of subsections. Work on this objective was delegated to a special subcommittee under the chairmanship of E. W. Schilling, and was reported upon separately by him. Supplementing this report, Mr. Mahood suggested that the Institute can only represent the electrical engineering profession as a whole in large cities by providing facilities such as compact and active technical groups for every branch of electrical engineering. Geographical restrictions would be another reason for the formation of groups, or subsections, as in the following instances:

1. Small groups of from 8 to 10 members such as at Amarillo, Tex., and Shreveport, La., over 300 miles from Section headquarters, and with isolated members in the Section closer to them than to headquarters.

2. Larger groups of from 10 to 20 members such as at Nashville, Tenn., and Winnipeg, Canada, which are long distances from Section meeting places.

3. Groups of from 10 to 20 members somewhat closer to headquarters, but whose size may indicate the formation of a Subsection.

4. Groups of 20 or more members such as at Ottawa, Canada, or Tacoma, Wash., which are almost large enough to become full-fledged Sections, as was the case originally at Dayton, Ohio.

The collection and printing of additional data on Section operation and management, objective number five, was more or less subordinated to the aforementioned major efforts, Mr. Mahood continued, with the exception of the materials prepared for discussion at the summer technical meeting. The committee rested on the data widely disseminated as a result of a national survey of Sections conducted several years ago.

The remaining objective was the preparations for the summer technical meeting, supervised by J. M. Thomson and R. M. Pfalzgraff. Two "clinics" for the discussion of problems relating to Section operation and management were arranged, one for large Sections and one for small Sections. (Reports of both clinics are given in succeeding items.)

Mr. Mahood completed his report with a tribute to the service of the Sections and Section officers. Through their meetings, he said, the Sections are contributing distinctly to the prosecution of the war; they have been a source of inspiration to electrical engineers to design and operate equipment more effectively; and many lessons learned under stress of war will be of permanent value in the coming peacetime economy.

REPORT ON SOUTH AMERICAN SECTIONS

O. C. Brill, reporting on the activities of the subcommittee on the development of South and Central American Sections, declared it to be their foremost policy that any action taken by the Sections committee should arise from a manifestation of interest on the part of AIEE members in those countries directly concerned, and especially those members who are nationals of the countries in question.

This interest has been manifested, Mr. Brill related, both from the governments of these countries and from their nationals who are members both of the local engineering societies and of the Institute. They seem to be looking to the AIEE, as probably the largest engineering society in the world, to assume the leadership in laying the groundwork for international engineering co-operation and collaboration in the Western Hemisphere.

In addition to cementing further international relations, by expanding our foreign membership to include engineers of those countries who are eligible, the establishment of Sections in South and Central America, with all the privileges appertaining thereunto, would benefit those AIEE members who are citizens of the United States but who, because of the exigencies of their work, must live in other countries.

To supply a factual foundation to the overtures of interest made in this direction, M. S. Coover, past chairman of the Sections committee, was delegated with the task of writing to AIEE members of record and also prominent local engineers in these countries for their views. Mr. Brill, reported on behalf of Professor Coover, that the majority of these responses favored such an establishment and that many were enthusiastic endorsements with offers of positive help in getting such Sections started.

All of the replies from Brazil, which now has 50 members, were favorable, and included representation from both United States and Brazilian nationals. Major Carlos Berenhauser, Jr., a prominent Brazilian engineer now on extended visit to the United States, joined the Institute that he might give the project his active support. Some of the replies from Argentina, with the second largest membership of 31, expressed doubt as to the feasibility of operating successfully a Section in that country because of the other engineering societies now in existence there, but other members, both United States and Brazilian nationals, considered it advisable. Martin del Corral (M '24), president of Avianco, the Colombian national airways, on a visit to New York recently, suggested the formation of a Section in Colombia. There are 17 AIEE members in that country, all of whom have expressed their sympathy with, and avowed their support of such a proposal.

In the face of such evidence, the committee believes that present efforts should be concentrated on Brazil and Colombia, and that once Sections have been established in those countries, they will provide experience to guide further expansion elsewhere. Progress has been slow because of the time required for correspondence, but in both those countries preliminary organizational work is now in process and petitions for such Sections probably will materialize in the early future. However, one of the obstacles to be overcome in organizing Sections in Latin-American countries is the

requirement in the bylaws that such a petition must be signed by 25 or more Institute members. Accordingly the committee has recommended to the board of directors that the bylaws be amended to reduce the requirement for signatures to a minimum of 15 members.

REPORT ON SUBSECTIONS

E. W. Schilling, reporting on the activities of the subcommittee on the development of subsections and technical discussion groups, declared that such action was more urgent than ever before now that travel restrictions were prohibiting members from driving the distances required to meet with their own Sections. He recommended that no energy be spared in organizing discussion groups, technical groups, or subsections, in order to prevent the rise of more specialized engineering organizations.

Many Sections have written that after a careful study of their own particular situations, the subsection idea is not adaptable to their needs. However, many letters have been received indicating that Sections are working on it and in some instances have already put them into operation (*EE, May '43, p. 218*).

A pamphlet has been prepared as a guide in the formation of subsections. This has been sent out to Section officers. Additional copies may be obtained by writing AIEE headquarters, 33 West 39th St., New York 18, N. Y.

Larger-Sections Clinic

Topics scheduled for discussion at the clinic on operation and management of larger Sections included: Section meetings, technical-group meetings, fellowship, financing District and national meetings, co-operation with war agencies, student activities, technical-paper competition, and related activities. The general plan followed in this clinic consisted in having an assigned delegate to open the discussion after which informal discussion by other delegates was solicited from the platform. G. W. Bower, chairman of the Philadelphia Section, presided, and A. C. Muir, secretary of the Philadelphia Section, acted as secretary. R. M. Pfalzgraff, member of the Sections committee, opened the clinic with an exposition of the clinic plan and the reasons underlying the holding of separate clinics for larger and smaller Sections.

President Harold S. Osborne pointed out that because of their greater numbers and resources the larger Sections have opportunities to do things that the smaller Sections cannot. He mentioned the opportunities that exist for the Section activities to serve as a model for the national organization; a successful Section activity might be desirable for ultimate adoption as a national activity.

Lead-off discussions on the various topics were given as follows:

Section meetings, A. C. Muir, Philadelphia Section.
Technical-group meetings, B. S. Cornell, New York Section.
Fellowship, L. F. Hunt, Los Angeles Section.
Co-operation with war industries, L. R. Gaty, Philadelphia Section.
Student activities, O. C. Rutledge, Schenectady Section.
Technical-paper competition, F. E. Keith, Chicago Section.
Membership transfers, R. G. Porter, Boston Section.
Publicity procedure, P. L. Hoover, Cleveland Section.
Instructional manual for Section officers, F. S. Black, Washington Section.
Participation in civic affairs, A. C. Muir, Philadelphia Section.

Discussion from the floor following these introductory discussions indicated that practices varied rather widely among the Sections in accordance with individual Section needs and preferences. The principal points brought out in the discussion are summarized in the following paragraphs.

SECTION AND GROUP MEETINGS

Most of the larger Sections have one or more organized technical groups called discussion groups, technical groups, divisions, or by other special names. Other Sections, particularly those covering large areas, have organized such groups on a geographical basis. The latter approach quite closely the form of the subsection, organization of which has been promoted during the past year (*EE, May '43, p. 218*). Among the newer groups reported as having been organized during the past year are one dealing with electrical problems for production foremen in the Philadelphia Section and an aircraft division of the Los Angeles Section (*EE, Apr. '43, p. 171*).

The majority of the larger Sections hold one regular Section meeting a month during the fall, winter, and spring months, at which a technical subject of broad interest is discussed. Supplementing these meetings, the various specialized groups hold meetings on more specialized technical subjects. In many instances attendance at the latter is reported as being on a par with attendance at the regular Section meetings. In Sections such as Michigan and Toronto, which cover large areas, meetings are held in the various cities of the Section territory; these are handled entirely by local committees.

Various degrees of joint activity with other societies were reported, but most of the Sections have at least one joint meeting a year. Most of the larger Sections also hold one meeting a year especially for students, at which prizes are awarded for student papers. Some of the Sections set aside one meeting as President's Night, and several invite the District officers to at least one meeting a year.

Meetings begin at from 7:00 to 8:15 p.m., depending on local conditions and needs. Some are preceded by business sessions, and in practically all instances the main event of the evening is followed by a discussion period. In some instances the meetings close with a period of social activities and refreshments. The Pittsburgh Section's student meeting is an all-day affair and includes inspection trips, a student meeting, and a dinner. Sections holding dinners preceding their regular meetings reported general success with this idea, but wartime restrictions are imposing difficulties here. Some Sections devote one meeting a year to a subject of interest to women, to which meeting they are invited.

Doctor Nevin E. Funk, AIEE President 1943–44, declared that the need for discussion or technical groups would increase, because the types of activity in electrical engineering are broadening all the time. The desirability of such groups increases as the size and diversity of the activities of the Section membership increase, he said, and the discussion group will be of material benefit in stopping the future branching off of some particular activity of electrical engineering into another specific national society.

FELLOWSHIP

Many of the Sections have reception committees which are charged with the duties of welcoming new members and guests at meetings and of helping the members to get acquainted. In some Sections, these committees also have charge of membership badges which are worn at all meetings; in some instances there are special badges for guests and new members, who receive special attention. In other Sections, the membership committees handle the so-called fellowship duties. In several Sections, either the membership or reception committee writes letters of greeting to new members and invites them to the meetings.

F. S. Black of the Washington Section said that the large number of visitors to that Section in recent years has created quite a problem. In addition to their regular reception committee, an associate chairman was appointed to contact members that have been transferred either temporarily or permanently to Washington. Meeting notices are sent to these individuals. The Section annually holds an outing which has proved highly successful, usually on a Saturday. Athletic events in the afternoon are followed by a dinner and evening program which includes installation of officers. Past chairmen are given special recognition at these outings.

A proposal to have a traveling representative associated with national headquarters to handle matters pertaining to the Sections was brought up and discussed. Reaction to this proposal as a postwar project was favorable.

FINANCING DISTRICT AND NATIONAL MEETINGS

The following recommendation was presented to the conference by the Sections committee for discussion:

"It is recommended to each District which has not already done so that they consider establishing a permanent District fund by small annual contributions from the Sections for financing District and national meetings, so as to eliminate ultimately the necessity for asking for contributions from business firms, as in the past. Such a plan would put the Institute on a self-sustaining basis and make it much easier for small Sections to hold such meetings, and would tend to encourage Sections to undertake the work involved, and if this became a general practice it would be appropriate to put the funds in the hands of the District secretary who would thereafter become District secretary-treasurer."

A. C. Stevens, secretary of the AIEE North Eastern District, reported that

such a plan has been operating in that District for 20 years and that it had been working very satisfactorily. Each Section in the District contributes a small amount to the fund annually, which has taken care of all needs so far. Other discussers favored the idea, but the difficulty of putting such a plan into operation, especially as far as the smaller Sections are concerned, was pointed out. No action was taken.

CO-OPERATION WITH WAR AGENCIES

Several delegates reported that their Sections had established special committees to co-operate with war agencies of one sort or another. Some of these committees have worked with the national committee on co-operation with war agencies, in handling locally assignments taken on by the national committee.

Chairman Bower reported on the war-production conference held in Philadelphia, one of the many such conferences held under joint sponsorship of engineering societies throughout the country. (Some of these have been reported in previous issues of *Electrical Engineering*.) As an outgrowth of that conference, a series of foremen discussion groups for production foremen was instigated as part of the war effort of the various technical societies in Philadelphia. The Philadelphia Section has taken the lead by organizing the first group and holding the first meeting. The meetings have been discontinued during the summer but will be resumed in the fall.

STUDENT ACTIVITIES

All of the larger Sections reported some activities especially for students. Usually, as already reported, at least one meeting is held especially for students during the season at which student papers are presented and prizes are awarded. In other instances efforts are made to stimulate student attendance at all Section meetings. Some Sections entertain the students at dinner preceding the students' meeting, each student being assigned to a regular Section member as host for the evening.

R. G. Warner, chairman of the committee on Student Branches, urged greater activity on the part of the Sections in connection with Student Branches during the coming year. He pointed to the uncertainties facing the Branches because of wartime conditions and urged Sections to take an active interest in providing speakers for the Branches.

Several other delegates reported that their Sections had established vocational guidance activities to aid boys in high schools who are interested in engineering as a career. Some of these provide speakers to high-school gatherings, and others contact the boys personally. One Section reported difficulty in carrying out guidance activity, because boys intending to study engineering need to decide before entering high school in order to choose the correct high-school course.

Doctor Charles F. Scott outlined briefly the student guidance work of the Engineers' Council for Professional Development, calling particular attention to the availability of Doctor William E. Wickenden's article "The Second Mile" which has been distributed widely (*EE, May '42, pp. 242-7*).

MEMBERSHIP PROBLEMS

Delegates from some of the Sections spoke of the difficulty of retaining the interest of older members. It was considered important to retain the interest of the older members as an appeal to new membership prospects.

Section membership committees of most of the Sections are composed of representatives of each of the principal industries in the Section territory with one or two additional members to represent the smaller industries. The importance of appointing a well-qualified member as chairman of the membership committee was stressed.

Some Sections anticipate difficulty in getting new members, because graduating students that normally would be good membership prospects are now going directly into the armed forces. In this connection, however, Chairman Bower read a letter from John H. Pilkington, chairman of the national membership committee, which reported a net increase in national membership of 1,217 over last year and urged that Section membership committees work right through the summer so as to take advantage of war conditions which favor an increase in the membership.

R. G. Porter reported the procedures followed by the Boston Section in regard to transfers. The membership committee reviews the list of local members annually; these members are allowed to stay on the records for three years. If they are of engineering caliber and capable of going on to the Associate grade, they are strongly urged to transfer. The membership committee also urges Associates to transfer to Member grade if qualified at the end of six years. Transfers from Member to Fellow are handled by a committee composed of past chairmen of the Section which reviews the qualifications of eligible candidates and fills out the necessary forms to be forwarded to headquarters. In the St. Louis Section a committee is appointed in alternate years which considers all transfers to Member and Fellow grades and makes recommendations.

PUBLICITY

P. L. Hoover related how the Cleveland Section formerly spent from $200 to $300 a year for meeting notices. With the organization of the Cleveland Technical Societies Council a publication called *Cleveland Engineering* was instigated, in which notices of all technical societies in Cleveland are listed. These are sent to all members of all of the participating societies, and the cost to the AIEE Cleveland Section is from $25 to $30 a year, or about one tenth of the former cost. The Pittsburgh and Schenectady Sections handle meeting notices in a similar manner.

CIVIC AFFAIRS

The Philadelphia Section participates in civic affairs on a joint basis with other engineering societies through the civic affairs council of the Affiliated Engineering Societies of Philadelphia, said A. C. Muir. Discussion-group meetings on civic matters of timely interest are held. Meetings have been conducted largely as forums followed by free discussion; many of the speakers have come from some of the more active 85 civic organizations in Philadelphia. In connection with civic planning, Mr. Muir reported, this group has been instrumental in the formation of a planning commission in the city of Philadelphia, made up of men recommended by the civic affairs council and some others.

Similar participation in local civic affairs was reported by the Schenectady Section through the newly organized Schenectady Engineering Council through which the activities of local engineering groups in Schenectady are co-ordinated.

Among other topics discussed briefly at the clinic on larger Sections was a manual for the guidance of Section officers and reports of past Section chairmen to national headquarters and new chairmen.

Smaller-Sections Clinic

Principal topics discussed at the clinic on smaller Sections were Section organization, officers and committees, relations with headquarters, financial matters, Section meetings, programs, functioning of Section meetings, membership, and student relations. W. J. Gilson, vice-president elect, of Toronto, Ont., presided. Before discussion began, delegates from two new Sections organized during the past year were introduced: Frederick Krug of the Montreal Section and E. J. Bates of the Dayton Section.

J. M. Thomson, vice-chairman of the Sections committee, opened the discussion by explaining the general plan of the clinic idea and the factors underlying the splitting of the delegates into two groups, representing, respectively, the larger and smaller Sections.

SECTION OBJECTIVE

Discussion of this topic led to the adoption of the following resolution:

"That an AIEE Section objective be adopted to read 'To have every qualified person in its territory actively at work promoting the Institute's objectives'; that the national secretary and national Sections committee be requested to obtain any approvals required, arrange to publicize this objective and develop plans for its effective use to promote Section activity including the compilation and dissemination of statistics which will give a better picture than is now available of how effectively each Section is carrying on the work of the Institute in its territory, with the hope that the influence of friendly rivalry between Sections as each strove to reach this objective may be brought into play as an effective force in promoting the Institute's work."

OFFICERS AND COMMITTEES

E. T. Pierson of the Lehigh Valley Section outlined that Section's procedure with regard to the selection of officers and committee chairmen. A list has been made of all members in the Section show-

ing what committee activity or what office or committee chairmanship has been held. This list showed that some members had held some office or committee chairmanship for the past 10 or 12 years while other equally active members had seldom been on a committee or never held an office. Efforts will be made, he said, to put to work those in the latter group.

In the Rochester Section, according to Delegate R. A. Whitford, the nominating committee is instructed to nominate members from the leading industries in the city plus two members to represent members not associated with larger industries.

M. H. Pratt of the Syracuse Section described the revised election procedures adopted by that Section during the past year. He said that in previous years ordinarily only one member of the executive committee had had previous experience on that committee. The new rules provide for three holdover members out of a total membership of seven on the executive committee. Several delegates reported that their Sections had followed similar procedures for some years.

There was some discussion on the tenure and duties of the Section secretary, practice varying considerably. Several Sections reported that the secretary normally holds office for two years. Chairman Gilson mentioned that in the Toronto Section meeting notices are handled by a commercial organization. For a comparatively nominal fee, the organization has the notices printed and takes care of circulating them to the membership, thus simplifying the secretary's duties.

Chairman E. T. Mahood of the Sections committee urged that retiring Section chairmen prepare final reports on the work of the Sections during the year, these reports to go to the new Section chairmen, chairman of the Sections committee, and national headquarters. Chairman Gilson read a resolution prepared by Mr. Mahood covering this suggestion. The resolution, which was adopted, follows:

"That it is the opinion of this group that it would be helpful to the Sections if arrangements were made to require the retiring chairman of each Section to make a report on the important developments which took place in the Section during his term of office and embodying recommendations for such changes, additions, or omissions in Section operation and management as his experience in office indicates would be beneficial to the Institute; copy to be sent to incoming chairman of Section, District vice-president, national secretary, and chairman of national Sections committee, for their review and action. With the establishment of this practice it may be possible to eliminate the notice and report on each Section meeting which is now sent to the chairman of the national Sections committee."

RELATIONS WITH HEADQUARTERS

First scheduled item to be discussed under this general topic was the matter of a manual on Section operation and management. The proposal was to have a manual prepared and circulated by National headquarters, perhaps in loose-leaf form, which would include all instructions and suggestions to Section officers in regard to the operation and management of Sections. These manuals would remain in possession of the Section secretaries and chairmen at all times and be passed from outgoing to incoming officers.

The discussion favored the production of such a manual and the following resolution was passed:

"That it is the opinion of this group that it would be helpful and desirable for headquarters to supply to each Section two substantially bound copies of a manual on Section operation and management covering all pertinent features of Section operation, duties of officers, suggestions of national committees, and other material assembled for ready reference; arranged by numbered subjects in loose-leaf form so that revision can readily be made; one copy to be maintained by the Section chairman and one by the Section secretary; to be passed on to incoming officers to assist them in their work; and that some committee be established to develop the contents of this manual."

A resolution on Branch reports also was proposed, discussed, and passed, as follows:

"That Branch reports in the future be sent to the national secretary, the District chairmen on student activities, the District vice-presidents, and the chairman of the national committee on Student Branches, but not to the chairman of the Sections committee."

The proposal to have a traveling AIEE representative associated with national headquarters to cover Section matters was discussed in some detail. Some delegates favored the proposal, expressing the opinion that such a representative would be very helpful to the officers of local Sections, whereas others thought the money required to employ such a man could be spent to better advantage in other ways. A recommendation that such a man be employed was shelved, finally, as the project did not seem feasible during the war.

FUND FOR DISTRICT AND NATIONAL MEETINGS

A proposal similar to that presented at the larger Sections clinic, that each District create a sum for financing District and national meetings, was discussed in some detail. R. G. Lorraine of the North Eastern District reported that such a fund had been operating satisfactorily in that District for some years. It has been the practice of that District in recent years to hold a technical meeting every year. Delegates from other Districts indicated that such a fund would have avoided some embarrassment over meeting deficits in the past. After further discussion the resolution was passed.

SUBSECTIONS

In regard to subsections, the Florida Section delegate stated that the subsection idea lends itself admirably to that Section. Subsections may be established in Miami, Jacksonville, and Tampa, and a meeting or two may be held by each of the three groups during the year. He suggested that the proposed manual of Sections operation and management be made available also to the subsections.

M. A. Faucett of the Urbana Section announced that that Section expects to organize subsections in Peoria, Springfield, and Decatur, Ill., during the coming year. The possibilities of subsections cooperating in joint activities with other engineering groups also was discussed.

PROGRAMS

The difficulty of the smaller Sections' getting good speakers for Section meetings occupied the principal attention of the delegates in this portion of the clinic. A proposal to establish a speakers bureau to aid in this problem led to passage of the following resolution:

"That there exists a need for some better arrange-

In attendance at the AIEE national technical meeting in Cleveland, Ohio, June 21–25, 1943, were R. W. Gemmell, manager of aviation engineering, Westinghouse Electric and Manufacturing Company; Lieutenant Colonel T. B. Holliday (A '41), electrical engineer, United States Army Air Corps, Wright Field, Dayton, Ohio, chairman of the AIEE air transportation committee; and W. A. Mechesney, manager of aviation application, Westinghouse Electric and Manufacturing Company. Lieutenant Colonel Holliday presided at the two sessions on electrical equipment for military aircraft of the meeting

means for making it possible for Sections to get in touch with persons who can make visits to various parts of the country to speak on Section programs, so that the programs of the various Sections can be better correlated with the traveling plans of such a speaker; that some definite channel should be established by action of the national committees to accomplish this either through a national officer or committee or through a District officer or committee. If done through a District officer, it is suggested that the duties of the District secretary be enlarged to include this function."

On this same general subject R. Felver of the Mansfield Section reported that the difficulty of getting expert speakers had led to scheduling a group of local members to speak at a meeting held by that Section during the past year on conservation of materials. He reported that the meeting was one of the most successful ever held by the Section and that the local speakers were found to be equally as good as those obtained from outside the Section. In view of this successful experience, the Section expects to have more meetings of that type. J. A. Northcott of the South Bend Section reported gratifying results with similar meetings in that Section.

A show of hands regarding the use of name tags at meetings showed that the majority of Sections do not use them, although several Sections reported highly satisfactory results in promoting fellowship by this means. Practically all of the Sections represented reported that attendance records are kept for Section meetings.

MEMBERSHIP

Various means of keeping the membership interested and active in Section activities were discussed. One means of stimulating interest among the older members reported by one Section was to ask some of the older members to contact other older members and ask them to attend meetings. Satisfactory results were reported.

The question of transfer fees was raised as being an obstacle to the promotion of transfers to appropriate grades of membership. H. H. Henline, national secretary, explained the reasons for the entrance and transfer fees. He pointed out that the reason for charging an entrance fee is that a person joining the Institute comes into an organization where he owns a share of the property, and assets of the Institute are valued at about $50 per member.

The question "Are all industries represented by membership as they should be?" brought forth some discussion on the matter of committee personnel. National Secretary Henline called attention to the stipulations of the bylaws in regard to committee appointments and said that efforts are being made to have committee membership distributed geographically as far as feasible, remembering that a committee must meet occasionally. In making committee appointments, he said, the President is guided largely by recommendations made by retiring chairmen of committees and by the Sections. Although all suggestions cannot be carried out, serious attention is given to them.

STUDENT RELATIONS

The clinic on smaller Sections closed with a discussion of student relations with the Sections. Chairman Gilson reported that one meeting a year is held by the Toronto Section in which four student papers are presented, two prizes being awarded. He reported highly satisfactory results with this annual affair. Students also attend the regular Section meetings, he said. Other Sections reported similar student relations.

R. G. Warner, chairman of the national committee on Student Branches, pointed out the difficulties expected for the remainder of the war in carrying on Student Branch activity. He urged the Sections to take active steps to help the Branches in any way possible, especially in obtaining speakers for Branch meetings. He suggested joint action on this problem with other engineering societies.

Inter-American Relations Subject of General Session

Attention was focused on the subject "The Engineer's Relation to Inter-American Affairs," at the general session held during the recent AIEE national technical meeting in Cleveland, Ohio. Feature addresses were delivered by: Major General Julian L. Schley, retired chief of the United States Army Engineer Corps, now director of transportation for the Office of the Coordinator of Inter-American Affairs; and R. E. Zimmerman, vice-president in charge of research and technology, United States Steel Corporation and president of the American Standards Association. A number of informal discussions rounded out the meeting.

In his opening remarks, AIEE President Harold S. Osborne said that the Institute has about 350 members in the Latin American countries, with one Section in Mexico, and that the establishment of Sections in South America is under consideration (see report of Sections committee elsewhere in this issue). Before introduction of the feature speakers, Captain B. H. Peake of the United States Marine Corps spoke briefly on the need for electrical engineers in the Marine Corps.

Addressing the session on the general subject of "Inter-American Affairs of Interest to the Engineer," General Schley spoke of the growing mutual confidence and understanding between the Americas, which is resulting in steadily improving inter-American relations. Declaring that "the electrical engineer has a very important stake in the progress of inter-American relations," he said, "the Americas are learning to work together for joint solution of common problems in an atmosphere of growing mutual trust. The many projects they are carrying on jointly today demonstrate the ability of the Americas to work together." Essential substance of General Schley's address is scheduled for publication in a subsequent issue.

Mr. Zimmerman in his address "Inter-American Co-operation in the Development of Standards," drew comparisons between previous international standardization activities with the European countries and those with Latin-American countries. He outlined the current progress of standardizing activities in various Latin-American countries. "A definite beginning," he said, "of the right sort we think has been made. . . . The American Standard Association, acting on behalf of its constituents, and with the indispensable assistance of its advisory committee on Inter-American co-operation, is making a determined effort to fortify and enlarge its initial undertaking, to the end that the opportunities now open in the field may be met, and that mutual good may result therefrom." Essential substance of Mr. Zimmerman's address also is scheduled for publication in a subsequent issue.

DISCUSSION

In the discussion period following the principal addresses, Major Carlos Berenhauser, Jr. (A '42), of the National Steel Company of Brazil reported on recent progress made by that company. "We already have in Brazil 20 blast furnaces in operation and we are rolling now, more or less, 350,000 tons of steel," he declared. All 20 of these furnaces use charcoal and have a comparatively small capacity, 50 to 100 tons per day. Studies now show that the grade of coal available in Brazil will produce good coke, and a blast furnace having a capacity of 1,000 tons per day and using coke is to be installed, he reported.

Commander T. F. Ball (F '38) of the United States Naval Academy mentioned the visits being made by representatives from Central and South America to the Naval Academy. He said that standards are uppermost in the minds of these representatives and that they are interested also in ordnance, seamanship, and navigation, but not to the same extent that they are in electrical and mechanical engineering. Another thing that they are deeply interested in is communication, he said, adding that "I believe that one of the best ways to build up good will is to have the proper form of communications among the Americas."

R. P. Crippen, international division, Ebasco Services, New York, N. Y., spoke on the human relationships entering into inter-American relations. He agreed with current reports to the effect that the feeling of friendliness between the peoples of North and South America has greatly increased recently, but urged that we "note what all of us as individuals can do." He stressed the importance of North American individuals, in their contacts with individuals of Latin-American countries, recognizing that those individuals are ordinary people like themselves and that they should be treated accordingly, not as specimens.

Stating that British and German standards had been powerful tools in getting business in Latin-American countries, J. B. MacNeill (M '36) of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., pointed out that those standards had been prepared from a point of view of selling equipment, which differs somewhat from the American point of view.

Most American standards have been prepared by people who are interested in the highest possible grade of service, and we may need alternate standards for export work, he declared. "The whole electrical standard situation has got to be changed to see if it is doing us the maximum good in international trade," he concluded.

Conference on Latin-American Relations

Supplementing the general session at the recent AIEE national technical meeting held in Cleveland, Ohio, was a conference devoted to the general question: "How Can the Institute Render Greater Service to Its Latin-American Members?" Several informal talks were given on various phases of the question, followed by open discussion. M. S. Coover (F '42), past-chairman of the Sections committee, presided. In opening the meeting, Professor Coover said that the nations of the North and South American continents already have recognized the need for closer collaboration on standards, and each has inherited therein real opportunities for significant technological and social gains in the years ahead.

Supplementing his address at the general session, R. E. Zimmerman, president of the American Standards Association, said that we now have an opportunity to do some of the things we should have done earlier in the direction of standardizing activities in the Latin-American countries, and emphasized the necessity of getting into a situation that is made to order. He stressed the importance of keeping standards and test codes dynamic rather than static.

The history of international standardization activities was outlined by L. F. Adams (F '42), General Electric Company, Schenectady, N. Y. He described first the International Electrotechnical Commission, organized in 1904, which had 27 member countries at the outbreak of hostilities in 1939. Three of these belong to the Western Hemisphere—Canada, Argentina, and the United States. Some dozen and a half standards have been produced by the IEC, but activities now are practically at a standstill because of the war.

The International Standards Association, Mr. Adams explained, is a federation of 20 national standardizing bodies, each of which is the central clearing house for industrial standardization work in its own country. The basis for the ISA was laid at an international conference in New York in 1926, and the American Standards Association joined in the fall of 1929. Activities of the ISA also have ceased because of the war. Although the name of this association implies an all-inclusive scope, Mr. Adams said, so far it has dealt mainly with mechanical subjects.

Alberto Magno-Rodrigues of the American Standards Association spoke briefly regarding relationships between Latin-American and the United States standardizing bodies, with particular reference to electrical standards. He pointed out that the American Standards Association has representatives in Argentina and Brazil, and he urged that the North-American countries help their neighbors to the South to achieve the same high standard of living that has come to be known as "the American way."

The status in Latin-American countries of technical books produced in the United States was outlined by W. S. Hall of the Henry M. Snyder Company, New York, N. Y., export representatives for American book publishers. He said that the demand for technical books is far greater than for any other type of books handled by that company. He reported a great increase in the sale of these books in those countries stating that the books have made a place for themselves by their form and content. As compared with French and German technical books, which had been used widely in Latin-American countries in the past, the North-American books are regarded as more modern and more practical. They are distinctly higher in price than the foreign books, a factor that was the prime deterrent to their sales before the war.

Regarding the technical-book situation after the war, Mr. Hull mentioned the following influencing factors:

"1. English is now the second language in Latin America rather than French.

"2. U.S.A. books are already strongly entrenched and have hurdled the difficult introductory period.

"3. Extensive industrial and engineering developments, in all of which American engineers are playing a leading part, lead naturally to a dependence on American books.

"4. The good-neighbor policy of our Government, intelligently administered in most respects, is showing results, and thousands of Latin Americans are buying and reading North American books who, five years ago, would not have touched one with a ten-foot pole."

In concluding, Mr. Hall urged that Spanish and Portuguese translation rights for technical books be released at as low a figure as possible and that some of our best-selling technical books be published in the United States in those languages under the original publisher's imprint. The actual printing of such books might be done in one of the Latin-American capitals, such as Mexico City, he suggested.

Major Carlos Berenhauser, Jr., (A '42) of the National Steel Company of Brazil commented on the application of North-American industrial equipment in Latin-American countries. He said that this equipment is better but costs more than equipment obtained from European countries, and that Latin-American countries do not have money to buy high-priced equipment. Industries in Brazil are not prepared to apply American standards directly, he said, but American standards can be used as a basis for the development of standards in that country. He predicted that the present inter-American co-operation will continue after the war and that the Latin-American market will not revert to European countries. In conclusion, he expressed the hope that a Brazilian Section of the AIEE eventually may be established.

Progress toward the formation of AIEE Sections in Latin-American countries was outlined by O. C. Brill, chairman of a special subcommittee of the Sections committee (details elsewhere in this issue). W. A. Del Mar (F '20) Phelps Dodge Copper Products Corporation, Yonkers, N. Y., offered the suggestion that the Institute solicit at least one Latin-American paper per year for AIEE meetings.

Major General Julian L. Schley, director of transportation for the Office of the Coordinator of Inter-American Affairs, supplemented his address at the general session with a few additional remarks at this conference.

Conference on Agricultural Electrification

A conference on agricultural electrification, featuring the presentation of five informal addresses, was held during the recent AIEE national technical meeting at Cleveland, Ohio. Because of the keen interest displayed in this subject, the conference, which began in the morning was extended into the afternoon for round-table discussion. W. F. Ogden, Jr., chairman of the AIEE committee on domestic and commercial applications, presided.

G. C. Neff (M '16), president of the Wisconsin Power and Light Company, Madison, in a historical review of the development of farm electrification, indicated the wide scope of future expansion of such a program. "It is my opinion," he said, "that rural electrification will not be producing full benefits to the farms of this country until some 4,000,000 of them are using an average of 500 kilowatt-hours a month."

The problem in making electric service available for farm operations, Mr. Neff explained, lies in maintaining the transmission system at a profit to both the farmer and the utility supplying the power. Farmers who think of electric service in terms of lighting only, and whose demands are not sufficient to support the cost of the lines, must be convinced by widespread and oft-repeated educational publicity that electricity must be applied to many more farm operations and the electric load must be increased if rural electric rates are to approach urban rates and if maximum efficiency is to be achieved.

The proper application of electric power to farm operations calls for a change in methods of farming, changes in farm management, and in the type and style of machines used. Operations which are now handled in urban centers could be handled on the farm profitably, such as processing of certain farm products, if proper machines and processes were developed. Labor can be saved since electric power can be operated for long hours under the control of automatic devices.

Mr. Neff recommended that the AIEE co-operate in a joint effort of farm and electrical groups to replace the Committee on the Relation of Electricity to Agriculture, which largely supervised this development from 1923 to 1939. He also recommended that the Institute or the American Society of Agricultural Engineers set up a

system for gathering farm electrification data to be made available to farm publications.

F. E. Watts of the *Farm Journal* and *Farmer's Wife* discussed the part played by electricity as an economic and social factor in the evolution of agriculture from its days as an isolated economy to the development of chemurgy—the industrial utilization of farm products, which involves the growing of farm crops to specification. He specially emphasized the productive efficiency of electrified farm equipment, and pointed out the importance to postwar economy of extending electricity to the business of farming.

He divided the postwar era into three periods: (1) the relief period, when food must be quickly provided for millions of people already starving; (2) the period of rehabilitation, when occupied countries, as well as those of the United Nations must be provided with machinery and tools to revive their own agricultural production; and (3) the period of reconstruction, wherein agriculture will be developed through greater productive efficiency. "It is not only an opportunity but a responsibility of the entire electrical industry," he stated, "to devote to the fullest its research, its engineering, and its sales ability to the solution of a problem which so fundamentally affects the future welfare of the American people."

Ruggedness and reliability of operation, an investment cost–efficiency ratio that takes into consideration the low annual-use periods of much farm equipment; provision of large power units, or semiautomatic smaller ones with other advantages to offset bigness; and maintenance of a low service rate by keeping demand low and the load factor and diversity high—these are some of the requirements wherein design of farm equipment differs from that of urban machinery, G. W. Kable, editor, *Electricity on the Farm*, explained in his address on "Application Engineering—a Key to Farm Production."

Mr. Kable suggested that engineers would do well to seek out the farmers themselves as a source of ideas and accomplishment in the practical use of electricity on the farm, and then supply their own technical assistance in developing them. Especially do the farmers' needs as regards cost, simplicity, and function need to be observed. Such action would be mutually beneficial to the agricultural industry, he thought.

He illustrated his talk with charts showing the low saturation of farm appliances as contrasted with the saturation of home appliances, and others showing that the average annual farm consumption of kilowatt-hours was raised to the high level it has attained through the large consumption of a very few farms, or less than five per cent of the total.

R. E. Hayman, rural-electrification engineer, Oklahoma Gas and Electric Company, Oklahoma City, delivered a paper on "Progress in Serving Oklahoma Farms." With the aid of varied charts he reported on the development of rural electrification in his region since the formation in his company of a department exclusively for the investigation and promotion of rural activities until the present. He was able to show exceptional progress in load growth throughout progressive reductions in overall costs.

The conference on wartime influences on lighting filled this auditorium at Nela Park during the recent AIEE national technical meeting at Cleveland, Ohio. E. M. Strong (M '40) presided

In attempting to analyze the future direction of this development, Mr. Hayman stated that engineers or manufacturers of electrical machinery had not gone far enough in their adaptation of standard electrical equipment to farm use. He suggested that electrical farm equipment be designed and constructed with the purpose and the requirements of the specific farm operation in mind instead of being a general adaptation of equipment primarily designed for other purposes.

The production of food is only one of the farmers' responsibilities today, said R. G. East, general agricultural agent for the Pennsylvania Railroad, Richmond, Ind., in a discussion on "Chemurgy and What It Means to Electrical Engineers." Entire crops, in some instances, and by-products from many others are being utilized for explosives, paper, clothing, housing materials, insecticides, paints, synthetic rubber, plastics, and many other industrial products through the application of new scientific techniques and new forms of machinery. Mr. East outlined the rapid advance of this relatively new industry, and discussed its effect on future electrical equipment.

A brief description of the slide film, "The Care and Maintenance of Electric Farm Equipment," by A. H. Hemker of the rural electrification section of the General Electric Company, Schenectady, N. Y., concluded the conference. The film is available for demonstration but was not shown during the conference because of time restrictions.

City Planning Aired at Conference on Civic Affairs

Continuing the series of conferences at recent AIEE national and District meetings, a conference devoted mainly to city and regional planning was held during the recent national technical meeting in Cleveland, Ohio. James H. Herron, Sr. (F '41) president, James H. Herron Company, Cleveland, Ohio, presided.

A report on the conference on city and regional planning held during the North Eastern District technical meeting in Pittsfield, Mass., April 8, 1943, was presented by F. A. Cowan (M '29), vice-chairman of the technical program committee. In this report Mr. Cowan abstracted the following six addresses delivered at that conference:

1. The Engineer's Stake in Community Planning, **Harold S. Osborne**, President AIEE, 1942–43.

2. Regional Development Through Industrial Research, **Lawrence W. Bass**, director, New Industrial Research Foundation, Boston, Mass.

3. The Place of Planning in a World at War, **Elizabeth M. Herlihy**, chairman, Massachusetts State Planning Board.

4. City Planning, **Roger L. Putnam**, lieutenant commander, United States Naval Reserve (formerly mayor of Springfield, Mass.).

5. The Foundations of Postwar Planning, **William Stanley Parker**, consultant, National Resources Planning Board, Boston, Mass.

6. Some Planning Problems of the Postwar Period, **Frederick J. Adams**, associate professor of city planning, Massachusetts Institute of Technology, Cambridge.

Based upon these addresses, Mr. Cowan reached the following conclusions:

General Considerations

1. The end of the war will make available man power and material which can be applied to meeting the demands for goods and services which have necessarily been deferred because of the war.

2. The transition period from war to peace attended by the demobilization of the armed forces, release of labor from war work, and conversion of factories to peacetime production will create many problems in sustaining the national economy.

3. For this transition to be orderly, it is necessary to plan now for the immediate postwar period, taking a long-range view lest steps be taken as expedients which later may be causes of regret.

4. It is generally believed that both public and private enterprise will have responsibilities in the development of the postwar period and that each should prepare its own program with a full appreciation of the problems and responsibilities of the other. Only by a co-ordinated plan can long-range programs be carried out effectively.

5. Planning comprises the projection of the needs of a city or region into the future and deciding the best way in which these needs can be met. It involves the physical aspects of industry location, housing and transportation, and the economic, legislative, and administration aspects. There is also the equally important problem of gaining the cooperation and support of the public for any program which has been formulated.

6. Since future requirements and developments cannot be forecast accurately, a planning body should maintain close observations of the progress of the program and current trends modifying the program as required to meet changing conditions.

From the Engineer's Viewpoint

1. City and regional planning work should be of increasing interest to engineers first because their

responsibilities as citizens should urge them to make available to planning groups their training and experience and secondly, for the benefits accruing to themselves from close association with planning work in connection with day-to-day engineering and long-range programming in their private professional activities. Because of this dual stake, the engineer should take the lead in organizing planning activities.

2. Interest and participation in planning work implies that engineers keep themselves conversant with developments in scientific and technical fields, not only their own but others as well. While the professional societies have always afforded opportunities along these lines, they can become increasingly helpful by formulating programs emphasizing the engineer's role in planning work. The local engineering councils established in many cities, comprising professional engineers and members of the national engineering societies, have been very effective in assisting not only official planning bodies, but also industrial and private enterprises having a need for setting up long-range programs. Through the national societies, the activities of these local councils can be co-ordinated on problems national in scope.

3. In order that his participation in planning work will be most fruitful, the engineer will need to be well informed on the financial, legislative, and administrative phases of long-range programs and of local governments. To this end, the local engineering councils can be of great help in fostering an interchange of ideas between the engineers and the local administration.

4. In the field of public relations, the engineering councils will need by judicious publicity, contacts with newspapers and local radio stations, and other organized groups experienced in such matters, to draw public support to their activities and to encourage the communities officially or as individual members to avail themselves of the services of the councils.

Copies of the report (AIEE miscellaneous paper 43-122, "The Engineer's Interest in City Planning") are available by mail from AIEE headquarters at 20 cents each.

H. W. Green, director of real property inventory of the city of Cleveland, supplemented the address on community planning which he delivered at the annual meeting (see separate item) by additional data on this subject. He emphasized that planning must be timed properly, and that postwar readjustment must be made without the complication of widespread unemployment. The question as to what proportion of workers must be employed during the postwar period must be answered, he said, but the answer given now may not hold after victory. Other related questions are: What will happen to price ceilings? How many single women will continue working? How many married women will continue working?

Mr. Green also presented statistics on the educational background of people 25 years of age and over. Three times as many adults never went beyond the sixth grade as have graduated from college, he said, and those who never went beyond the eighth grade number four times the college graduates. Trained leaders must come from the educated groups, he said, which are being depleted by death and Selective Service. Calling attention to some of the difficulties of working with lawyers on civil committees, he urged engineers to *learn* community leadership. The engineer first must learn what is going on in the community, then determine his attitude on various questions, and finally decide what he should do.

J. T. Howard, planning engineer, city of Cleveland, outlined the benefits of city planning to the engineer. Stability of community areas and of taxation he indicated as the principal benefits to the engineer as a citizen. Advantages to industry are: co-ordination of the transportation system, stabilizing of residential areas and of taxation, and keeping labor reasonably happy. Mr. Howard pointed out that lack of planning had resulted in the wasting of many public and private funds in the over-expansion of suburban residential areas during boom periods. In conclusion, he said that community planning must have, and is acquiring, a scientific basis of operation.

In the discussion that followed, various questions were raised and were answered by one of the principal speakers. Mark Eldredge (F '33), War Production Board, Washington, D. C., pointed out that the session had been devoted primarily to the planning of new areas. What about old areas needing reconstruction? he asked. Mr. Howard replied that the redevelopment of old areas is one of the toughest problems facing planning agencies. He expressed the opinion that such areas must be redeveloped "by the square mile" and preferably by private enterprise.

A representative of the AIEE Philadelphia Section reported that that Section had been instrumental in forming a discussion group on civic affairs which later was expanded into a joint activity with other engineering groups in Philadelphia. Through this agency, civic problems have been brought to the attention of engineers, and the group has acted in an advisory capacity to civic authorities in the city.

War Problems Dominate Education Conference

Because of the new importance which servo-mechanisms, the basis of innumerable operations in our armed forces, have assumed, a talk covering their basic principles, fundamental definitions, and their classifications, by C. F. Green, aeronautic-marine department, General Electric Company, Schenectady, N. Y., was of special interest to the educators at the morning session of the conference on education held on June 24, during the national technical meeting.

Defining the servo-mechanism as an automatic control system which derives its control from a component part of the system actuated by some function of the difference, or so-called error, between the input signal and the output response of the system, Doctor Green arrived at these parts common to all servo-mechanisms: input element, error measuring element, control element, servo-motor, and the load. The servo-motor supplies the power for the output load and response. This power is controlled by amplification from the control element which is actuated through response from the error measuring element. The error measuring element receives the input signal, compares it with the output response, measuring the error, or its derivative, or its integral, functions. These error functions are combined in the control element and by this means the desired response of the system is brought into play through the application of various forms of control power. The control power may be hydraulic, amplidyne, thyratron, or multiple-contact. The closed system which characterizes servo-mechanisms means that the output response should possess the same rotational motion, displacement, voltage magnitude, speed value, and so forth, as the respective input signal quantity, and that the response is fed back to the error measuring element.

Animated cartoon movies, as a method of aiding students form mental concepts of a number of correlated simultaneous functions, were demonstrated by C. E. Gus, professor, New York (N. Y.) University. Professor Gus offered to assist anyone interested in using the easily prepared animated cartoons in teaching theoretical subjects.

An introductory talk on the psychology of learning and teaching under accelerated conditions, as in the military training programs, delivered by H. H. Davis, vice-president, Ohio State University, Columbus, was also part of the morning program.

The afternoon session of the conference was given over to a consideration of the many problems which have resulted from the Army and Navy Specialized Training programs. Many of the grave economic and administrative problems which have arisen for the colleges participating in the training program were discussed. Because of the lack of response to the call of the Army and Navy for trainees, the actual enrollment, in several instances, fell far below that promised to the colleges. Some courses were abandoned altogether. In addition the delayed response of prospective trainees caused the instruction schedules set up by the colleges to be ignored. In an attempt to dispel some of the existing confusion about the objectives of the training programs, Lieutenant Colonel F. H. Pumphrey (M '25) undertook definition of the Army's purposes while Lieutenant Commander T. F. Ball (F '38) presented the Navy's point of view. Colonel Pumphrey declared that the Army hoped the program would steer a middle course between "glorified job training" and "a super-engineering program." It wishes emphasis laid on imparting adequate basic theory of circuits, machines, and electronic apparatus. Instruction on the operation and maintenance of the highly complex types of Army field equipment will be given ASTP graduates at Army service centers. On the other hand, Commander Ball pointed out, the Navy, which has no corresponding service centers, would prefer that Navy trainees' instruction cover the operation of its specialized apparatus and the development of manual dexterity for "trouble shooting" and field servicing.

According to Colonel Pumphrey the Army is seeking to train two classes of men: noncommissioned officers whose responsibilities entail close supervision of the operation and maintenance of complicated field equipment, and officer personnel, capable of leadership, versed in the basic theory of

the apparatus under their command, and possessing a working knowledge of its operation and field maintenance.

In regard to the teaching of servomechanisms in the ASTP, Colonel Pumphrey indicated that the instruction in this course would probably be limited to a few schools that were qualified by equipment and personnel for this particular type of work. (Robin Beach, chairman of AIEE committee on education.)

Conference on Teaching Ultrahigh-Frequency Phenomena

The conference on teaching of ultrahigh-frequency phenomena and procedures held during the summer national technical meeting was one of a series of such conferences since the original held at the Massachusetts Institute of Technology some time ago. The program comprised three scheduled informal talks which were followed by a general discussion. J. R. Martin (A '35) of the Case School of Applied Science, Cleveland, presided.

In the opening talk, J. G. Brainerd (M '39) University of Pennsylvania, Philadelphia, spoke of the mixed groups now taking military technical training courses in the colleges and of their varied educational backgrounds. Maxwell's equations, Bessel functions, and related matter can be given in the junior or senior year of an engineering course, he stated. Teaching the Fourier integral, however, requires more time. Professor Brainerd also drew some comparisons between the meter-kilogram-second system of units and other systems, from the standpoint of their usefulness in the ultrahigh-frequency field.

Calling attention to the differences in fundamental concepts involved, H. J. Reich (A '32), University of Illinois, Urbana, pointed out the difficulty of introducing ultrahigh-frequency courses into so-called power courses or regular electrical-engineering courses. Trigger circuits, cathode-ray circuits, and similar applications in the electronics field have been worked into the present ultrahigh-frequency program. A student who has studied the ultrahigh-frequency fundamentals and electronics can handle the Klystron and related equipment satisfactorily but will not be exactly an ultrahigh-frequency specialist. In regard to the postwar situation, Professor Reich said that we must continue to teach fundamentals and not attempt to cover the many ultrahigh-frequency applications in detail.

Ultrahigh-frequency laboratory problems were discussed by W. C. Osterbrock (M '41), University of Cincinnati, Ohio. He said that a committee had been appointed to establish designs for ultrahigh-frequency laboratory equipment, but that so far the committee had not functioned. The problem, therefore, was left to the schools, and the schools had improvised laboratory equipment under some difficulties. He called attention to the scarcity and difficulty of obtaining equipment and the confusion encountered with suppliers as regards priorities and other wartime restrictions. He emphasized the importance of a thorough grounding in the practical handling of equipment but reported that the teaching of these aspects varies among the schools. Among the experiments prescribed at the initial MIT conference, those involving directive antennas have proved the most difficult.

In the general discussion, Commander T. F. Ball (F '38) of the United States Navy declared that the Navy needs men who both understand and can operate equipment. Stress fundamentals first, he urged, but also show the men how to operate the equipment.

Lieutenant S. G. Reiches of the United States Army described the operation of radio locaters (radars) in England. Women handle the actual operation and the minor servicing of this equipment, while the administration is handled by men. The administrative personnel know the fundamentals of ultrahigh-frequency phenomena and their application to radio locaters but do not perform operation or maintenance duties. He emphasized the fact that operation counts in the field, not theory.

Conference on Safety

The fundamental problems of safety are the same whether an organization be large or small, but the methods of approach in solving these problems must be adapted to the size and type of organization. A high degree of safety can be achieved in the smallest enterprise if the management will inculcate safety training along with other operational teaching activities, and if the responsibility for safety efforts be placed with the supervisory force in addition to their regular duties. Such were the conclusions derived from the conference on safety, held during the recent national technical meeting in Cleveland, Ohio, June 22. Frank Thornton, Jr. (F '21), chairman of the AIEE committee on safety, presided.

O. S. Hockaday (M '28), superintendent of transmission, Texas Electric Service Company, Fort Worth, presented the main paper of the session, "Practical Accident Prevention in Small Groups." Two prepared discussions followed his paper, the first by S. B. Taylor of the Reliance Electric and Engineering Company, Cleveland, Ohio and the second, "A Practical Safety Program for the Small Plant," by J. G. Jackson (A '08), director of engineering, Square D Company, Detroit, Mich. Open discussion concluded the program.

Student Branch Counselors Confer at Technical Meeting

The combining of Branch and subsection activities in regions where such an arrangement would be a greater convenience for members who might otherwise have to travel long distances to participate actively in Section affairs, was recommended by E. T. Mahood, chairman of the AIEE Sections committee, in his opening remarks at the conference of Student Branch counselors held June 23, during the Cleveland technical meeting. In addition, he suggested that should this arrangement be adopted, financial assistance be given to the subsection by its Section.

Proposals to differentiate between part-time and full-time graduate students and to lift the five-year limitation on enrolled students were submitted to the conference by P. C. Cromwell, chairman of a special subcommittee on graduate student enrollment. His report advised that part-time graduate students who are working as engineers are suitable candidates for associate membership. However, the report advocated that full-time graduate students with more limited incomes be given an additional term of from two to four years as enrolled students. The report was adopted by the conference and recommended to the board of directors for further action.

Discussing the development of professional consciousness among engineers, C. F. Scott (HM '29) professor emeritus, Yale University, New Haven, Conn., requested that the Branches aid in fostering a professional attitude among students. He urged that more students familiarize themselves with W. E. Wickenden's "Second Mile," (*EE, May '42, p. 242*) as a step in this direction.

D. C. Jackson (F '12) professor emeritus, Massachusetts Institute of Technology, Cambridge, reported on the progress of the engineering code of ethics recently completed by a special committee of the Engineers Council for Professional Development. The code was approved by the Council at its 1942 annual meeting for submission to the boards of directors of the participating societies. Doctor Jackson defended the code of 31 items against charges that it is too lengthy, pointing out that in 1908 the lawyers drew up a code of 32 items which has since grown to 46. The conference voted to appoint a committee to bring the subjects of engineering as a profession and the professional code of ethics to the attention of the Student Branches. The committee appointed was: W. H. Gamble (M '33), South Dakota State College, Brookings, *chairman*, A. J. B. Fairburn (M '34), University of Akron, Ohio, and E. M. Strong (M '40), Cornell University, Ithaca, N. Y.

As chairman of the subcommittee for maintaining contact with students in the armed forces, E. M. Strong announced that an AIEE *Bulletin* containing, in condensed form, material from the news section of *Electrical Engineering* had been printed and mailed to members in the services (see page 374).

E. W. O'Brien (M '37) chairman of the subcommittee on student prizes presented a report recommending that student prizes be established for each District. These would be awarded at the closing session of the conference, convention, or regional meeting at which the District paper pres-

entation contest takes place. First prize would be $50, second $25, third $15, and fourth, $10. The conference accepted the report and recommended its adoption by the board of directors.

In the general discussion following the scheduled business of the conference, Lieutenant Commander T. F. Ball (F '38) recounted his experiences, at Annapolis, with a "clinic" where a new group of 300 engineering graduates of schools throughout the United States is received every 16 weeks. From the average group about 10 per cent can pass an examination on elementary work in circuit theory and machines, while one third can pass an examination covering the fundamental courses of physics, chemistry, and mathematics. After a one-month refresher course 103 out of one group of 300 passed a test in these fundamentals and 27 of the 103 passed a test on elementary electricity. Numerical mistakes accounted for a large number of the failures. Commander Ball pointed out that instructors at the Naval Academy must now be graduates of accredited engineering schools.

Robin Beach (F '35), Polytechnic Institute of Brooklyn, informed the conference that a bulletin on movies available for Branch technical meetings may be had at AIEE Headquarters. Chairman R. G. Warner of the committee on Student Branches presided.

AIEE Issues "Bulletin" for Members in Armed Forces

First issue of the AIEE *Bulletin*, a four-page 8½- by 11-inch quarterly publication for AIEE members in the armed services and the merchant marine of the United States, has recently been completed and mailed. The second number is expected to be issued in September.

Designed to reach all members in the armed forces who are unable to receive *Electrical Engineering*, the *Bulletin* is comprised of condensed news items on Institute activities and on the related developments on the home front of interest to them as engineers. Members can co-operate in this wartime enterprise by sending in items of interest to those in the services and by keeping Institute headquarters informed of their latest addresses.

SECTION • • • • •

New AIEE Section at Dayton

The new AIEE Section at Dayton, Ohio, comprised of three counties released from the Cincinnati Section and five counties from the Columbus Section, held its organizational meeting June 15, 1943. Formation of the new Section had been authorized by the executive committee at its meeting on May 27.

Section bylaws were adopted and the following officers were elected for 1943–44:

Chairman—L. J. Fritz (M '42) district plant engineer, Ohio Bell Telephone Company.

Vice-chairman—E. R. Martin (M '31) American Aircraft Manufacturing Company.

Secretary-Treasurer—J. W. Gehrke (M '41) distribution engineer, transmission and distribution engineering department, Master Electric Company.

Assistant Secretary-Treasurer—F. S. Himebrook (M '39) electrical engineer, Master Electric Company.

Directors—J. M. Coombs (A '41) and E. J. Bates (A '45) National Cash Register Company; H. E. Deardorff (A '37) supervisor, system planning engineering, Dayton Power and Light Company; W. A. Dynes (A '35) chief electrical unit, specifications branch, materiel division, United States Army Air Corps, Wright Field; and G. I. F. Theriault (A '32) welding engineer, Frigidaire division, General Motors Corporation.

The following officers were elected for a period of two years:

Directors—E. Herzog (M '29) senior electrical engineer, United States Army Air Corps, Wright Field; A. W. Janowitz (A '11) sales agent, lamp department, General Electric Company; and W. B. Riner (A '34) associate electrical engineer, electrical department, Wright Field.

Speakers Invited to Visit Sections in Western Districts

AIEE Sections in the four geographical Districts of the Institute west of the Mississippi River have expressed an interest in inviting eastern engineers visiting their part of the country to address their Section meetings. Arrangements are being made for the secretaries of these Districts to secure the names of such visitors for transmission to the Sections. Companies with which these engineers making western trips are affiliated are requested to so inform the District secretaries whose names and addresses are as follows:

District 6; F. C. Howard, Iowa-Nebraska Light and Power Company, 144 South 12th St., Lincoln, Nebr.

District 7; R. G. Kloeffler, Kansas State College, Manhattan, Kan.

District 8; M. A. Sawyer, Box 5300, Metropolitan Station, Los Angeles, Calif.

District 9; A. Boyer, Anaconda Copper Mining Company, Butte, Mont.

ABSTRACTS • • •

TECHNICAL PAPERS previewed in this section will be presented at the AIEE national technical meeting, Salt Lake City, Utah, September 2–4, 1943, and are expected to be ready for distribution in advance pamphlet form within the current month. Copies may be obtained by mail from the AIEE order department, 33 West 39th Street, New York 18, N. Y., at prices indicated with the abstract; or at five cents less per copy if purchased at AIEE headquarters or at the meeting registration desk.

Mail orders will be filled AS PAMPHLETS BECOME AVAILABLE

Air Transportation

43-140—Radio-Noise Elimination in All-Metal Aircraft; *Fred Foulon (M '42). 30 cents.* Aircraft in which the electrical system is not shielded require special consideration to be given their radio circuits. The prevention of noise energy coupling to the receiving lead-in circuits is achieved by adhering to simple radio layout requirements. These requirements incorporate the use of the metal structure as the major shielding element so as to provide the required screening of the lead-in conductors from the local noise fields. The proper noise isolation can always be obtained more economically by such design layout than by entirely shielding the electrical system, as this method requires the use of a great deal of shielding and bonding that produces no useful result. Aircraft radio noise problems are analyzed and a complete noise survey, which requires only simple test methods, is outlined. Methods of correction of existing radio noise, involving the use of additional shielding and filtering, are outlined.

43-145—High-Voltage Ignition-Cable Design for Aircraft; *H. H. Wermine. 15 cents.* Design and operation of high-voltage ignition systems on combat aircraft-engines, together with widely varying climatic conditions in the extensive theaters of war, are factors which have placed unusually severe service demands on high-voltage ignition cable. Cable manufacturers have accordingly accelerated their efforts toward the development of new and improved designs in order to meet these conditions. Consideration is given to the specific conditions under which ignition cable is expected to function during service life. Reasons for unsatisfactory performance of certain types are given also. New materials and designs are contemplated on the basis of performance under service conditions. A departure from the customary cable testing methods is made in the development of simulated-flight testing used to evaluate cable suitability. Close co-operation of the engineers of the air services, engine manufacturers, and cable manufacturers has accelerated the development of new and improved designs and, it is expected, will continue to do so.

43-146—Aircraft Transformers—Small and Light; *O. Kiltie (A '31). 15 cents.* The necessity for light weight and small size in aircraft transformers is very evident, since any reduction in space and weight will reflect larger capacities for fuel and bomb loads. Various types of transformers have been developed recently, such as three-phase to single-phase, single-phase to three-phase, two-phase to three-phase, three-phase to two-phase, combination a-c to d-c transformer-rectifier self-regulated units, miniature instrument type, and a line of general purpose aircraft units with kilovolt-ampere ratings ranging from 100 volt-amperes to 5 kva, with weights ranging from 0.8 pound to 9.5 pounds, and operating at ultimate temperatures of 225 degrees centigrade. Included are vibrator inverter transformers, voltage stabilizers, and high-voltage and low-voltage booster ignition coils.

43-149—Parallel Operation of Airplane Alternators; *D. W. Exner* (*A '42*). *15 cents.* A-c auxiliary power systems are under development for the new large airplanes and, for maximum reliability, parallel operation of alternators must be accomplished. Experience with the two auxiliary-engine-driven 400-cycle plants on the XB-19 airplane is reviewed and conclusions reached on the requirements of a modern system. The problems of driving and paralleling main-engine-driven alternators are discussed and recommendations are made.

Electrical Machinery

43-136—Some Measures of Electrical-Brush Disintegration; *M. S. Coover* (*F '42*), *E. E. Jones* (*A '40*). *15 cents.* In making further explorations into the characteristics of electrical-brush disintegration, a need appeared for the introduction of such concepts as wear resistance, wear resistivity, wear susceptance, and wear susceptibility. The concepts, as developed, are believed to be significant and useful tools that may further an understanding of the basic problems of sliding electrical contacts. For example, they offer means for making a valid comparison of electrical brushes and brush materials insofar as wearing qualities are concerned. Moreover, they provide a clue to the proper consideration and evaluation of the larger number of variables that are engulfed in brush disintegration.

43-137—Turn Ratio of the Capacitor Motor; *T. C. McFarland* (*M '32*). *20 cents.* This paper is an extension of a previous paper entitled "Current Loci for the Capacitor Motor." The effects of changing the turn ratio, based on the assumption that machine constants are unchanged, are discussed. The current loci for different values of turn ratio are determined for a machine of fixed constants, and modifications of suggested rules previously stated are given to account for turn ratio. The effects of turn ratio on certain performance characteristics are demonstrated. A comparison of equal-watt and equal-volt-ampere designs is given.

43-138—Temperature Limits and Measurements for Rating of D-C Machines; *F. A. Compton, Jr.* (*A '39*). *20 cents.* Existing industrial practice for determining temperature rise of d-c machines is based on measurements with thermometers. While experience indicates that such machines have satisfactory service records, tests using resistance measurements disclose the existence of considerably higher internal temperatures than those indicated by thermometer. Greater accuracy and consistency are possible with the resistance method, and it affords a truer indication of winding temperature. It is suggested that the resistance method be used more generally and ultimately recognized in the standards. Detailed recommendations for making temperature measurements by resistance are presented. Correlation of temperature rises determined by resistance and thermometer methods are given on variously ventilated and insulated machines. Suggested values of temperature limits measured by resistance to supplant the now standard thermometer values are presented. The information applies to low voltage (approximately 600 volts maximum) d-c machines with form-wound armature coils and conventional field coils.

Electric Welding

43-139—The Automatic Welding-Machine Starter and Its Relation to Maximum Utilization of Power and Facilities; *N. E. Porter* (*A '43*). *15 cents.* Many electric arc welding applications are of such a nature that the welding machine is running with no load for a large percentage of the operating time. With this low utilization factor or "arc time," no-load power consumption becomes an appreciable item. In plants employing many machines there will be long leads between the machines and the work, either by necessity or for convenience. Under these conditions, the practicability of expecting the operator, or welder, to turn his machine on and off each time he plans to weld is certainly very remote. The automatic welding machine starter has been developed to shut down the machine during the normal no-load running periods. Automatic starters have been in operation under average shipyard welding conditions for the past few months. Application of the automatic starters effects a very appreciable saving in power cost, often 25 per cent or more. In addition a marked reduction in average demand on distribution systems is realized so that additional machines, up to 75 per cent, may be added without further power facilities expenditure.

Industrial Power Applications

43-144—Rectifer Drive for D-C Motors; *K. P. Puchlowski* (*A '43*). *25 cents.* This paper gives a brief outline of the principle of armature voltage control of d-c motors by means of rectifier tubes with controlled angle of ignition. The characteristics and disadvantages of the elementary rectifier-motor system are discussed in some detail. The speed regulation of such a thyratron control system is compared with that of a conventional adjustable voltage drive. Means and circuits for improving speed regulation of a rectifier drive are discussed and results are illustrated with experimental speed-torque characteristics. The problem of automatic acceleration is outlined and current-limit acceleration controlled by means of electronic tubes is discussed. The advantage of a mixed current limit and time-delay acceleration is pointed out and a circuit for automatically controlled acceleration is presented. An outline of the advantages and features of a modern rectifier drive concludes the paper.

43-150-ACO—A New Method of Measuring Contact Bounce; *P. H. Estes. 15 cents.* In many relay applications, it is essential that the operation of the relay contacts be positive, with mechanical bounce reduced to a minimum. Measurement of bounce is, therefore, an important aid in arriving at the proper design of the contacting mechanism. A simple device for making bounce measurements employs a special recording paper, sensitive to voltage, applied by means of a stylus wire. The contacts being tested are connected to the stylus through an amplifier, so that voltage is applied to the stylus whenever the contacts are together. Bounce, by causing contact separation, removes the potential from the stylus. By moving the paper under the stylus, a broken line, black when the contacts are together and white when they are separated, is obtained. If the paper is moved at a predetermined speed, exact measurement of each bounce may be made in milliseconds. The same device may be used for measurement of operating time, release time, accuracy of repetitive operations, and the effect of residual and eddy currents on operation. It is particularly useful on relays where these values are extremely small.

Instruments and Measurements

43-152—A New Simple Calculator of Load Flow in A-C Networks; *W. E. Enns* (*A '37*). *15 cents.* The paper describes a network calculator of an entirely new form, and of unusually small proportions in its physical size and in the simplicity of its electrical elements. This board may be used to determine the flow of real and reactive power, voltage conditions, losses, and reactive requirements in a-c networks. A single constant voltage supply unit, a-c or d-c, with a multiplicity of voltage taps is used as the power source to the board and eliminates the need of generator and load units. With this design a small number of resistance units may be used to set up completely a complex a-c network consisting of many circuits. Simple network calculators of this type may fill the gap now existing between the use of tedious analytical methods and the complete a-c board for making load-flow studies in a-c networks.

Power System Applications

43-141—Application of 720-Cycle Carrier to Power Distribution Circuits; *J. L. Woodworth* (*Application Pending*). *30 cents.* This paper analyzes the 720-cycle transmission characteristics of 60-cycle power circuits involved in the application of a carrier channel for remote control of street lights, off-peak loads, and other services. Short-line methods generally applicable to urban distribution circuits are developed for predicting the carrier performance from

values usually available from 60-cycle distribution studies, such as, conductor size and spacing, load kilovolt-amperes, power factor, and short-circuit kva. The relative advantages of introducing the carrier voltage across, or in series with, the 60-cycle generator, are compared and illustrated. The effects of tap lines and distributed 60-cycle load on the 720-cycle voltage distribution along long lines are considered. Methods of co-ordinating the joint application of power factor correction capacitors and carrier control on the same system are outlined.

Power Transmission and Distribution

43-133—Lightning Surges Transferred from One Circuit to Another Through Transformers; *P. L. Bellaschi* (*F '40*) *25 cents.* Through the medium of transformers surges are transferred from circuits exposed to lightning to circuits considered otherwise nonexposed. The latter may connect to rotating machines, or to industrial apparatus of inherently low impulse insulation level, or to apparatus of old design as a rule even more vulnerable to surges. The surge transferred consists essentially of an electrostatic and an electromagnetic component: the first results from capacitance coupling; the second depends on the turn ratio and short-circuit inductance between windings. Terminal conditions contribute to determine the amplitude, wave form, and duration of the surge transferred. This paper presents the results of an investigation. Simplified methods of calculating transferred surges are derived to assist, in a practical way, those engaged in this type of protective studies. This contribution serves besides to call attention to the vital importance transferred surges may assume under certain conditions.

43-151—The Effects of Mutual Induction Between Parallel Lines on Current Flow to Ground Faults; *J. I. Holbeck* (*M '36*), *M. J. Lantz* (*Application pending*). *15 cents.* The paper deals with the effects of mutual induction between parallel transmission lines on current flow to ground faults and discusses methods of solving problems involving mutual induction between transmission lines of the same or different voltages. Diagrams and examples illustrate the effects of mutual induction between paralleling lines on the magnitudes and direction of the ground currents flowing in the lines to a ground fault. Examples are shown demonstrating how improper relaying may occur if the effects of some of the more complicated mutual induction problems are neglected.

Protective Devices

43-142—Dethermalizing Arc Quenchers; *L. F. Hunt* (*F '38*), *F. H. Cole* (*M '42*). *15 cents.* This paper describes dethermalizing arc quenchers that cause the arc and its associated space to be cooled by the controlled flow of oil through and around the arc. The first 16-kv breaker was built in 1936. Field tests were made and the results are given in the paper. Later, a new 230-kv breaker was equipped with dethermalizing arc quenchers and field tests were made again. The record of operation of these dethermalizers during the past six years has shown no deterioration of oil, contacts, or insulating materials of the interrupters, and they have cleared all short circuits and line dropping incident to normal operation. From this operating experience, it becomes apparent that this type of arc quencher will result in the very minimum of maintenance and at the same time give a maximum of system protection.

43-143—A New One-Cycle Directional-Overcurrent Relay; *W. C. Morris* (*A '38*). *15 cents.* This paper describes the first successful one-cycle directional-overcurrent relay which incorporates a new principle of memory action in addition to directional control and which is proof against false operation under any practical system operating condition. Directional-overcurrent relays with time delays higher than several cycles have been available for many years, but there is no such relay of the instantaneous type available. Many incorrect relay operations have been traced to the common practice of adding instantaneous attachments to directional-overcurrent relays without realizing the complete lack of co-ordination. Our tests show that an instantaneous plunger relay cannot be co-ordinated with any available directional element, so two induction-cylinder elements were employed. The new feature, "memory," secures a sufficient time delay, of the order of one-half cycle, to give correct performance.

43-148-ACO—Development, Tests, and Operating Record of the Dethermalizer Arc Quencher; *F. H. Cole* (*M '42*), *C. P. Garman* (*M '26*). *25 cents.* With the advent of Boulder Dam power in Los Angeles over long-distance transmission lines, a basic need developed for medium and high voltage circuit breakers with shorter interrupting times. Many of the circuit breakers on the United States Bureau of Reclamation's system were of an early design and did not meet this need. Research at River Power Plant led to improvements of the arc quenchers which had operated successfully in circuit breakers on the Bureau's system since 1933. A circuit breaker of an early design was equipped with the improved device and tested in the field at system voltage. Further improvements were made as the tests indicated. Operating experience of 115-kv and 132-kv circuit breakers equipped with arc quenchers of the original and improved types, showing that shorter interrupting times have been realized, is presented.

43-147—A New-Type Carrier Relay Protection; *E. M. Wood* (*F '43*), *H. W. Haberl* (*A '26*), *and F. A. A. Bailly* (*A '28*). *20 cents.* The paper describes an installation of power line carrier of the single frequency voice-actuated type of which the primary function is for operating communication. On this is superimposed a relaying function for the respective transmission circuit, using tones modulated on the carrier in connection with basic stepped-range directional-impedance line-relay protection. The operation of the instantaneous impedance relaying at either end starts the carrier tone. Transmitted to the other terminal, this is used to by-pass the timer on the second range relay at that terminal, giving, thereby, practically simultaneous clearance of the line for faults at any location in the line. High power (400 watts) is used to assist in transmission of the signal past line faults. The novel features are the combination in one set of the high grade communication with relaying signals and the use of the trip-transfer principle with impedance relaying.

Safety

43-134—Effect of Frequency on Let-Go Currents; *C. F. Dalziel* (*M '39*) *Eric Ogden* (*Enrolled Student*), *C. E. Abbott. 20 cents.* This paper on electric shock covers the subject of sine wave let-go currents for both men and women, and contains an analysis, based on experiments made on a relatively small number of subjects, which permits improved accuracy in predicting the response for large groups. It should be of especial interest to persons who have had accidents in which they barely escaped "freezing" to an electrified conductor, and also to those interested in electrical safety.

43-135—Effect of Wave Form on Let-Go Currents; *C. F. Dalziel* (*M '39*). *25 cents.* This is a companion paper to the foregoing one, and concludes the study of let-go currents before the experiments were terminated for the duration. This paper extends the analysis to cover various wave shapes including sine waves, direct current, and complex wave forms containing both alternating and direct current components. Conclusions regarding reasonably safe electric currents are based on the criterion that a safe current is the let-go current for 99½ per cent of a large group of healthy subjects. These papers are the most comprehensive treatment of the subject yet published as the analysis permits predicting currents of a specified degree of safety for men, women, and children for wave forms likely to be found in practice for a frequency range from 5,000 to 10,000 cycles and direct current.

PERSONAL • • • •

Stanley Stokes (A '16, F '29) consulting electrical engineer, Union Electric Company of Missouri, St. Louis, has been appointed chief engineer. He was graduated

from the University of Missouri with the degree of electrical engineer in 1912 and did construction work for the Mississippi River Power Distributing Company until 1915. In 1915 he became sales engineer for the Electric Company of Missouri predecessor of the Union Electric company. In 1917 he was made assistant vice-president of that company. From 1918 to 1925 he was general superintendent for outlying districts for the Union Electric company. In 1925 he was made assistant vice-president, and consulting engineer in 1935. From 1932 to 1934 he served as AIEE vice-president. **G. P. Gamble** (M '36) formerly assistant general superintendent of electrical operations, has been appointed superintendent of production. A graduate of the University of Virginia, he has been associated with the Union Electric company since 1929. He had previously been employed by the General Electric Company, Schenectady, N. Y., and by Stone and Webster, Boston, Mass. **E. L. Hough** (A '25, M '38) formerly electrical engineer, has been named chief design engineer. A graduate of the University of North Dakota (1922), he has been with the Union Electric company since 1928. Prior to that he was associated with the General Electric Company at Schenectady, N. Y., and at St. Louis. **C. H. Kraft** (A '17, F '31) formerly superintendent of distribution, has become superintendent of distribution and transmission. He has been with the Union Electric company since 1915 and was made superintendent of distribution in 1925.

William Fondiller (M '15, F '26) electrical apparatus development director, Bell Telephone Laboratories, Inc., New York, N. Y., has been appointed assistant vice-president of the Bell Laboratories. Mr. Fondiller, who was born in Russia in 1885, was graduated from the College of the City of New York with the degree of bachelor of science in 1903. From Columbia University he received the degrees of electrical engineer in 1909, and master of arts in 1913. He entered the engineering department of the Western Electric Company, New York, N. Y., in 1909, engaging in general laboratory work on telephone apparatus. From 1913 to 1923 he was in charge of various experimental groups working on telephone apparatus. In 1923 he was made head of the company's general development laboratory. Since 1925 he has been with Bell Laboratories. He has been a research associate of the engineering department of Columbia University, New York, N. Y., since 1934. The holder of numerous patents and author of several technical papers, he is a fellow of the American Association for the Advancement of Science. **R. G. McCurdy** (A '16, F '34) director of transmission engineering, Bell Telephone Laboratories, Inc., succeeds Mr. Fondiller as director of electrical apparatus development. A graduate of the University of California, Mr. McCurdy was employed in the department of development and research, American Telephone and Telegraph Company, New York, N. Y., from 1916 to 1934. Since 1934 he has been at Bell Laboratories. He is a member of the Acoustical Society of America and Tau Beta Pi.

W. J. Wooldridge (A '06, F '38) manager of electrical sheet sales, Allegheny Ludlum Steel Corporation, Brackenridge, Pa., has retired. Born in Cornwall, England, in 1878, he commenced his electrical career in the testing department, General Electric Company, Schenectady, N. Y., in 1893. He was transferred to the transformer engineering department at Lynn, Mass., in 1895, and in 1898 was placed in charge of the commercial engineering section. In 1903 he was transferred to Pittsfield, Mass. He had charge of electrical sheet manufacture and sales for the Wheeling Steel Company, Portsmouth, Ohio, from 1919 to 1923, and for the Empire Steel Corporation, Mansfield, Ohio, from 1923 to 1934. In 1934 he became manager of electrical sheet sales for the Allegheny company. He is a member of the American Society for Testing Materials, the Iron and Steel Institute, and the British Iron and Steel Institute.

Samuel Ring (A '09, M '28) supervisory engineer, Consolidated Telegraph and Electric Subways Company, New York, N. Y., has retired. He holds the degrees of bachelor of science (1900) and electrical engineer (1915) from Cooper Union. He entered the employ of the New York (N. Y.) Edison Company as tester and foreman in 1905. In 1906 he became assistant general foreman and in 1907 cable inspector. From 1908 to 1911 he was employed on the design and construction of the underground distributing system of the Portland (Oreg.) Railway, Light and Power Company. As statistician he returned to the New York Edison Company in 1911. In succession he became assistant underground superintendent in 1913, general foreman in 1921, assistant engineer in 1923, and division engineer in 1929. In 1940 he was appointed supervisory engineer with the Subways company. He has been active in the various Edison employee associations.

W. T. Booth (M '23) engineer in charge of machine switching apparatus design, Bell Telephone Laboratories, New York, N. Y., has retired. He received the degree of bachelor of science from Cooper Union in 1905. From 1900 to 1907 he worked as designer of apparatus for Lambert Schmidt Telephone Manufacturing Company. In 1908 he joined the Western Electric Company, New York, N. Y., where he also worked on apparatus design. From 1911 to 1914 he was attached to the staff of the European engineer at Berlin, Germany, and Antwerp, Belgium. During World War I he served as his company's engineering representative to the Army and Navy. He continued with the Western Electric Company until 1925, when he was given charge of machine switching apparatus design at Bell Laboratories. The duties of repaired apparatus engineer were later added to his work.

F. B. Philbrick (A '20, M '38) formerly Pacific Coast district manager, is now president and general manager of the Gamewell Company, Newton Upper Falls, Mass. A graduate of the Massachusetts Institute of Technology, Mr. Philbrick commenced his engineering career in the testing department of the General Electric Company, Schenectady, N. Y., in 1918. During 1919 and 1920 he was an instructor at the Massachusetts Institute of Technology, Cambridge. He joined the Gamewell Company in 1920 as assistant engineer. In 1924 he became engineer in charge of the drafting room and in 1927 assistant chief engineer. From 1929 to 1937 he was district sales manager of the Pacific Coast states. Since 1937 he has been manager for that district.

M. K. Toeppen (A '21, M '21) formerly principal telephone engineer, Federal Communications Commission, Washington, D. C., has been appointed assistant chief engineer and chief of the common carrier division of the Commission. He has been associated with the Commission since 1931.

R. L. Kaylor (M '36) formerly captain, United States Army, has been promoted to the rank of major and is serving in the South Pacific. He is on leave of absence from Bell Laboratories, Inc., New York, N. Y.

D. J. Maxcy (A '36) formerly junior engineer, Consolidated Edison Company of New York, Inc., is on war leave of absence to work for Sanderson and Porter, Engineers, New York, N. Y.

R. P. Watts (A '38) formerly captain in the United States Army, has been promoted to the rank of major and is director of the Post Engineer Division, Camp Butner, N. C.

J. P. Moran (A '39) formerly tester, Consolidated Edison Company of New York (N. Y.) Inc., has been given a wartime leave of absence to join the Induction Heating Corporation, New York, N. Y.

H. C. Hamilton (A '23, M '26) head of the test and research section, Boston (Mass.) Edison Company, has been elected president of the Engineering Societies of New England.

R. V. Jones (A '20) formerly engineer, American Telephone and Telegraph Company, New York, N. Y., has been commissioned major in the United States Army.

OBITUARY • • • •

William James Foster (A '07, F '16) retired consulting engineer, General Electric Company, Schenectady, N. Y., died July 2, 1943. He was born September 17, 1860, at Argyle, N. Y., and was graduated from Williams College with the degree of bachelor of arts in 1884. He received the degree of master of arts from Williams College in 1885 and that of master of science from Cornell University in 1891. He held the doctor of science degree from Cornell

University. From 1886 to 1890 he was teacher of physics and mathematics at the Pottstown (Pa.) High School. In 1891 he entered the Thomson-Houston Company, Lynn, Mass., as a designer. In 1894 he was transferred to Schenectady, N. Y., where he became engineer in charge of electrical design of a-c motors. In 1929 he retired. During his 25 years as design engineer, he took an active part in the design of every important a-c machine built by the General Electric Company. Many of these machines have made outstanding records for long service. He was leader in the development of subdivided conductors to avoid stray losses, the use of radial ventilating systems in turbine alternators, the development of varnished cloth insulation, and the procurement of sinusoidal-voltage wave forms. In 1930 he was awarded the AIEE Lamme Medal, "for contributions to the design of rotating a-c machinery." He served on the AIEE electrical machinery committee from 1920 to 1930, on a special committee on the history of the electrical industry from 1932 to 1934, and on the meetings and papers committee for 1928–29. He was the author of several papers and pamphlets. A member of Phi Beta Kappa, he was a fellow of the American Academy for the Advancement of Science and a member of the Political Science Association.

Claus Marius Bang (A '21) manager, hydroelectric power development, Bowater's Newfoundland Pulp and Paper Mills, Ltd., Corner Brook, died October 14, 1942. Born July 21, 1882, at Copenhagen, Denmark, he received the degree of bachelor of science in mechanical engineering from the Polytechnical Academy, Copenhagen, in 1906. From 1906 to 1910 he was an assistant in the electrotechnical laboratory at the academy. After a year and a half spent on a traveling scholarship in Europe, he joined the Northern Electric and Manufacturing Company, Montreal, Que., in 1911 as a draftsman and engineer. During 1913 he worked as designing draftsman in the electrical department of the Cedars Rapids Power and Manufacturing Company, Montreal. From 1915 to 1918 he was engaged in tool designing and munition plant layout for the Canadian Allis-Chalmers, Rochfield, Que., the Montreal Munition Company, Lachine, Que., the Montreal Tramways Company, and Caran Brothers, Montreal. He was electrical designing engineer with the Wayagamack Pulp and Paper Company, Ltd., Three Rivers, Que., from 1918 to 1924. In rapid succession he worked for the Newfoundland Power and Paper Company, Ltd., Corner Brook, in 1925 and 1926, for the Mistassini Power and Paper Company, Ltd., Montreal, in 1927, and for the Lake St. John Power and Paper Company Ltd., Dolbeau, Que., during 1928 and 1929. From 1930 to 1937 he was electrical superintendent for the Canadian International Paper Company, Three Rivers. In 1938 he became manager of hydroelectric development for the Bowater's company. He was a member of the Danish Society of Civil Engineers.

Louis Christian Marburg (A '02, M '10, F '13) secretary and treasurer, Marburg Brothers, New York, N. Y., died June 26, 1943. Born March 8, 1876, at Wiesbaden, Germany, he attended college at Charlottenburg, Hanover and Darmstadt, Germany. In 1898 he was employed in the drafting room of the Sprague Electric Company, New York, N. Y. He continued with the General Electric Company, Schenectady, N. Y., from 1899 to 1904, as designer of railway motors and power distribution systems. From 1904 to 1910 he was connected with the Bullock Electric Company, Cincinnati, Ohio, and its successor, the Allis-Chalmers Manufacturing Company, Milwaukee, Wis. Until 1906 he was concerned chiefly with general railway engineering and power station design. As engineer in the contracting department during 1907 he had charge of all mechanical and electrical engineering undertaken by the department. From 1907 to 1910 he was engineer of the gas and mill engine department. In 1910 he became a partner in the firm of Marburg Brothers. He was a member of the joint conference committee which formed the American Engineering Council, the American Society of Mechanical Engineers, and the Society of Automotive Engineers. He was a past-president (1926) of the Montclair Society of Engineers.

Franz J. Dommerque (A '94, M '96, F '13) consulting engineer, died December 7, 1942, at Bad Godesburg, Germany. Born November 27, 1861, at Duisburg, Germany, he completed the mechanical engineering course at the Polytechnic Institute, Munich. In 1887 he entered the machine shop of Hartmann and Company, Offenbach, Germany, and during 1888 he worked on the construction of power plants for the Schmidt-Douglas Electrical Company, Bradford, England. Coming to the United States in 1888 he entered the employ of the Western Electric Company, Chicago, Ill., as draftsman and designer. From 1889 to 1892 he was associated with the Thomson Electric Welding Company, Lynn, Mass. He was chief draftsman for the Chicago (Ill.) Telephone Company from 1893 to 1900 when he became chief engineer for the Kellogg Switchboard and Supply Company, Chicago. In 1911 he returned to the Western Electric Company, New York, N. Y., and in 1912 was made special telephone engineer for the company in Europe. In 1913 he retired. During 1922 and 1923 he was director of foreign development for the Federal Telephone and Telegraph Company, New York, N. Y.

John Clarence Gaylord (A '11, M '26) superintendent of hydroelectric generation, Southern California Edison Company, Ltd., died June 2, 1943. He was born June 5, 1884, at Clinton, Conn., and received the degree of bachelor of science in electrical engineering from Throop Polytechnic Institute in 1906 and from the Massachusetts Institute of Technology in 1908. As a laboratory and shop assistant he worked for the Southern California Edison company during 1908 and 1909. From 1909 to 1912 he was instructor and assistant professor at the University of Southern California, Los Angeles. He returned to the Southern California Edison company in 1912 as draftsman and station designer. In 1918 he was placed in charge of the electrical division of the engineering department. He became assistant electrical design engineer in 1928 and engineer in the hydro division in 1932. In 1940 he was made superintendent of hydro generation. He was a member of the company's committees on system planning and fire prevention. During 1935–36 he served as Los Angeles Section secretary and as chairman for 1936–37.

Milton Wayne Pollock (M '31) vice-president, Cia. Impulsora de Empresas Electricas, S. A., Mexico City, Mexico, died December 9, 1942. He was born June 2, 1892, at Foosland, Ill., and received the degree of bachelor of science in electrical engineering from Colorado College in 1917. He commenced his career as an electric engineer for the Guanajuato (Mexico) Power and Electric Company from 1920 to 1922. In 1922 he joined the Electric Bond and Share Company, New York, N. Y., as assistant engineer, becoming assistant sponsor engineer in 1925 and sponsor engineer in 1928. From 1929 to 1934 he was chief engineer for the Cia. Hidroelectrica Guanajuatense, S. A., Mexico. As chief engineer he joined the Cia. Impulsora de Empresas Electricas, S. A., in 1934 and in 1940 became vice-president. He was chairman of the AIEE Mexico Section for 1934–35. During World War I he served as a captain in the coast artillery.

Barrett Morris Merrill (A '17, F '28) manager of power supply, Washington Water Power Company, Spokane, died June 15, 1943. He was born at Syracuse, N. Y., April 21, 1880, and was graduated from Purdue University with a bachelor of science degree in electrical engineering in 1902. From 1902 to 1905 he worked for the Puget Sound Electric Railroad Company, Seattle, Wash., as substation operator and superintendent of electrical properties. Since 1905, when he was employed as assistant superintendent of light and power in charge of transmission, he had been with the Washington Power company. In 1910 he was made assistant superintendent in charge of power, and in 1918 superintendent of power. He became superintendent of light and power in 1928. In 1940 he was appointed manager of power supply.

Fred J. McCormick (M '37) plant protection engineer, Wisconsin Telephone Company, Milwaukee, died in November 1942. He was born May 28, 1882, in Waukeoka County, Wis. He entered the employ of the Wisconsin Telephone Company in 1899. Until 1913 his various assignments brought him into contact with operation, construction, maintenance, and manage-

ment of telephone systems. From 1913 to 1920 he designed toll and exchange plants and was company representative in foreign wire relations. In 1920 he was made toll construction engineer and in 1932 plant protection engineer. As such he specialized in foreign wire relation problems.

James William Perry (A '03, M '13) retired vice-president, Johns-Manville, Inc., New York, N. Y., died March 9, 1943, at Monterey, Calif. Born at Parkersburg, W. Va., March 18, 1868, he began his association with the Johns-Manville company as a salesman for its predecessor, the H. W. Johns Manufacturing Company, Philadelphia, Pa., in 1888. In 1893 he became manager of the electrical department and as such was transferred to the New York office of the Johns-Manville company. In 1925 he was appointed vice-president and retired in 1929.

Roger Cleveland Newberry (A '39) lieutenant in the United States Army has been killed in action. Born July 16, 1916, at Cleveland, Ohio, he was graduated from Yale University in 1938 with the degree of bachelor of engineering. He was employed in the service department of the Otis Elevator Company, Youngstown, Ohio, from 1938 to 1941 as junior salesman and service and maintenance man. In 1942 he became an air cadet in the Army.

MEMBERSHIP

Recommended for Transfer

The board of examiners, at its meeting on July 22, 1943, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Albright, A. S., acting ch'ef of research, Detroit Edison Co., Detroit, Mich.
Balch, E. C., chief engr., Michigan Bell Telephone Co., Detroit, Mich.
Chase, P. H., chief engr., Philadelphia Electric Co., Philadelphia, Pa.
Higbie, H. H., prof. of elec. engg., University of Michigan, Ann Arbor, Mich.
Langstaff, H. A. P., elec. engr., West Penn Power Co., Pittsburgh, Pa.
Miller, W. C., supt. of elec. system, Detroit Edison Co., Detroit, Mich.
Moore, A. D., prof. of elec. engg., University of Michigan, Ann Arbor, Mich.
Wagner, H. H., chief electrical engr., Pennsylvania Transformer Co., Pittsburgh, Pa.

To Grade of Member

Alter, J. M., lead inspector, Test Dept., Pennsylvania Railroad, Altoona, Pa.
Armstrong, H. R., test engr., Detroit Edison Co., Detroit, Mich.
Barcus, E. D., engr., Southern California Telephone Co., Los Angeles, Calif.
Bary, C., rate research engr., Philadelphia Electric Co., Philadelphia, Pa.
Bell, B. H., operating electrical engr., New Orleans Public Service Inc., New Orleans, La.
Boast, W. B., asst. prof., Iowa State College, Ames, Iowa.
Boice, W. K., elec. engr., General Electric Co., Schenectady, N. Y.
Brauer, H. H., senior engr., Stromberg-Carlson Co., Rochester, N. Y.
Cheverton, J. A., station engr., Wisconsin Electric Power Co., Milwaukee, Wis.
Christensen, J. F., asst. elec. engr., Aqua Systems, Inc., New York, N. Y.
Gakle, W. F., chief engr., Kuhlman Elec. Co., Bay City, Mich.
Holliday, T. B., Lt. Col., U. S. Army Air Forces, Wright Field, Dayton, Ohio.
Hughes, G. N., elec. engr., Aluminum Co. of America, Alcoa, Tenn.
Jeynes, P. H., depreciation engr., Public Service Elec. & Gas Co., Newark, N. J.
Johnson, J. S., asst. prof. of elec. engg., Missouri School of Mines and Metallurgy, Rolla, Mo.
Livingston, O. W., elec. engr., General Electric Co., Schenectady, N. Y.
Maddrey, W. D., division engr., Texas Electric Service Co., Eastland, Texas.
Mathes, K. N., elec. engr., General Electric Co., Schenectady, N. Y.
Matthewson, D. E., asst. engr., Prudential Insurance Co., Newark, N. J.
McCarry, O. P., elec. engr., General Electric Co., Pittsfield, Mass.
Nelson, O. L., engr., Southern California Telephone Co., Los Angeles, Calif.
Northrop, B. S., associate prof. of elec. engg., Cornell University, Ithaca, N. Y.
Ramo, S., electronics engr., General Electric Co., Schenectady, N. Y.
Ries, C. F., asst. to supt. of substation, Detroit Edison Co., Detroit, Mich.
Robnett, V. P., Lt. Comdr., USNR, U. S. Naval Academy, Annapolis, Md.
Sage, R. S., engr., General Elec. Co., Schenectady, N. Y.
Sayres, D. B., switchgear circuit designer, General Elec. Co., Philadelphia, Pa.
Schmidt, M. L., section engr., General Electric Co., Fort Wayne, Ind.
Sheldon, E. E., senior engr., General Electric Co., Bridgeport, Conn.
Stevens, R. F., Lieut., Civil Engineer Corps, USNR, Denver, Colo.
Tulloch, D. F., asst. head of distribution, Boston Edison Co., Boston, Mass.
Vassil, P. N., Capt., Signal Center Teams, CSCS, Camp Crowder, Mo.
Vikoren, O. B., engr., Philadelphia Electric Co., Philadelphia, Pa.
Walker, D. S., chief engr., Industrial Scientific Corp., New York, N. Y.
Ware, L. A., associate prof. of elec. engg., University of Iowa, Iowa City, Iowa.
Way, K. J., telephone engr., U. S. War Dept., Fort Monmouth, N. J.
Westrate, M. C., elec. engg. dept., Commonwealth & Southern Corp., Jackson, Mich.

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Names of applicants in the United States and Canada are arranged by geographical District. Any member objecting to the election of any of these candidates should so inform the national secretary before August 31, 1943, or October 31, 1943, if the applicant resides outside of the United States or Canada.

To Grade of Member

Belt, T. A. E. (Re-election), Hercules Powder Co., Lawrence, Kans.
Brown, E. H. (Re-election), Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Cochrane, H. H. (Re-election), Montana Power Co., Butte, Mont.
Dupuis, R., Universite Laval, Quebec, Que., Can.
Fleming, R. A., Major R.C.O.C., Ottawa, Ont., Can.
Griswold, L., Gen. Elec. Co., Phoenix, Ariz.
Hatch, T. E., Liquid Cooled Eng. Div., Toledo, Ohio.
Hogan, J. P., Post Engr. Office, Camp Tyson, Tenn.
Hoot, D. W. (Re-election), Nicaro Nickel Co., New York, N. Y.
Nygren, E. F., Boeing Aircraft Co., Seattle, Wash.
Pemberton, H. L., Alum. Co. of Canada, Ltd., Montreal, Que., Can.
Shelton, F. H., Empire Dist. El. Co., Joplin, Mis.
Simm, S. G. (Re-election), U.S.C.G. Hq., Washington, D. C.
Smith, M. W., Gibbs & Hill, Inc., Pittsburgh, Pa.
Sorensen, E. M., Sorensen & Co., Inc., Stamford, Conn.

To Grade of Associate

United States and Canada

1. North Eastern

Bridgett, A. W., U. S. War Dept., Boston, Mass.
DeLucia, V. E., Machlett Labs., Inc., Norwalk Conn.
Foster, C. M., Chas. T. Main, Inc., Boston, Mass.
Hedtler, P. A., Dewey & Almy Chemical Co., Cambridge, Mass.
Mullin, C. G., Central N. Y. Pr. Corp., Syracuse, N. Y.
Phelps, B. E., Int. Bus. Mch. Corp., Endicott, N. Y.
Thomas, H. E., West. Elec. & Mfg. Co., Boston, Mass.
Woodworth, J. L., Gen. Elec. Co., Schenectady, N. Y.

2. Middle Eastern

Farrow, C., Republ. Steel Corp., Cleveland, O.
Glass, R. A., Carnegie Ill. Steel Co., Youngstown, Ohio.
Hart, F. G., Cramp Shipbuilding Co., Philadelphia, Pa.
Linsenmeyer, J. Z., West. Elec. & Mfg. Co., East Pittsburgh, Pa.
Mullen, C. E., Duquesne Light Co., Pittsburgh, Pa.
Reifschneider, P. J., Gen. Elec. Co., Philadelphia, Pa.
Ricketts, R. E., Aircraft Radio Laboratories, Dayton, Ohio.
Suomi, N. A., May-Fran Engr. Inc., Cleveland, O.
Weadon, R., Kaiser Cargo, Inc., Brista, Pa.

3. New York City

Caruso, C. G., Watson-Flagg Engg. Co., New York, N. Y.
Lange, R. C., Gibbs & Cox, New York, N. Y.
Lindstrom, P. J., Staten Island Edison Corp., Staten Island, N. Y.
Oliver, J. W., Jr., U. S. Army, Fort Monmouth, N. J.
Shieh, F. H., Nat. Res. Co. of Chinese Gov., New York, N. Y.
Taflett, M. S., Radio Tel. Inst., New York, N. Y.

4. Southern

Jones, C. C., U. S. Army, Camp Wheeler, Ga.
Murphy, A. L. (Re-election), 3836 Central Ave., St. Petersburg, Fla.
Peet, H. D., Curtiss-Wright, Corp., Louisville, Ky.
Temple, C. V., T.V.A., Chattanooga, Tenn.
White, R. M., Higgins Ind., Inc., New Orleans, La.

5. Great Lakes

Amundson, R. H., Line Material Co., South Milwaukee, Wis.
Chick, S. G. (Re-election), Ford Motor Car Co., Willow Run, Mich.
Hardisty, T. W., U. S. Navy, Milwaukee, Wis.
Herziger, W. J., Allis-Chalmers Mfg. Co., West Allis, Wis.
Ison, L. M., Pub. Serv. Co. of Ind., Indianapolis, Ind.
Jaeschke, R. L., Dynamatic Corp., Kenosha, Wis.
Rogers, E., Pub. Serv. Co. of North. Ill., Waukegan, Ill.
Stomberg, V., Gen. Elec. Co., Ft. Wayne, Ind.
Swenson, C. F., James Stewart Co. Inc., Chicago, Ill.
Timm, H. D., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Wood, C. O. (Re-election), Goodman Mfg. Co., Chicago, Ill.
Zambreno, R., U. S. Maritime Comm., Chicago, Ill.

7. South West

Tarpley, J. W., U. S. Navy, Austin, Texas.

8. Pacific

DeConly, J. C., Holmes & Narver, Cons. Engrs., Los Angeles, Calif.
Hutchison, E. G., Jr., U. S. Navy, Los Angeles, Calif.
Miller, F. A., Douglas Aircraft Co., Santa Monica, Calif.
Nipper, A. H., Capitol El. Co., San Diego, Calif.
Shuey, R. L., U.S.N.R., Pacific Fleet, San Francisco, Calif.
Smith, L. S., U. S. Navy Yard, Mare Island, Calif.
Wolff, T. L., Southern Pac. Co., San Francisco, Calif.

9. North West

Bruce, W. F., U. S. Navy, Spokane, Wash.
Edgecomb, H. C. (Re-election), Boeing Aircraft Co., Seattle, Wash.
Franzen, R. J., Graybar Elec. Co., Ltd., Seattle, Wash.
Hansen, V. (Re-election), War Prod. Board, Portland, Oreg.
Kirk, C. H., Mont. Power Co., Butte, Mont.
Pelles, J. S., Jr., Army Air Base, Great Falls, Mont.
Sayner, W. V., Signal Corps, U. S. Army, Seattle, Wash.

10. Canada

Davison, J. L., Alum. Co. of Can., Ltd., Montreal, Que., Can.
Hyatt, E. E., Alum. Co. of Can., Ltd., Montreal, Que., Can.
King, A. L., Ferranti Elec. Ltd., Mt. Dennis, Ont., Can.
Laurence, J., École Polytechnique, Montreal, Que., Can.
Smith, E. G., Alum. Co. of Canada, Ltd., Montreal, Que., Can.
Thomson, J. A., Alum. Co. of Canada, Ltd., Montreal, Que., Can.
Walton, E. N., Philips Elec. Works, Ltd., Montreal, Que., Can.

Elsewhere

Hodgkinson, W. A., Ferranti, Ltd., Chadderton, England.

Total to grade of Associate
United States and Canada 62
Elsewhere, 1

OF CURRENT INTEREST

Inventors Council Seeks Solution to Military Problems

The National Inventors Council is soliciting suggestions leading to the solution of problems which have been posed to our armed forces by actual field operations. War conditions have demonstrated the need of various devices or methods not practically available and have shown the desirability of substitutes or alternatives for devices and methods already in our possession. Additional lists of current military needs may follow this present one. The list recently released by the Council includes:

1. A method of removing the tetraethyl lead from leaded gasoline to make it usable in stoves, lanterns, and small engines.

2. An inexpensive metal suitable for Quartermaster tableware with requisite strength, freedom from corrosion by food acids or alkalis, durability, and attractiveness.

3. Suitable substitute for rubber for insulating wire that is flexible and durable.

4. Detectors of enemy personnel, who may be approaching unseen, on jungle trails or fences or similar barriers.

5. Sonic or supersonic means or methods of signaling in the field.

6. Improved means or methods of signaling the identification of ground troops to friendly airplanes and vice versa.

7. Improved traction devices for wheeled vehicles of all types. (Present chains and other devices are cumbersome, inconvenient to apply and remove, and lack sufficient traction.)

8. Tracks for tractors and other motorized equipment which will operate efficiently in snow and extreme cold.

9. Better air cleaners for use on tank engines and the like which are more effective than present cleaners and require less maintenance.

10. Methods of quick-action waterproofing for enabling vehicles to ford water several feet deep, without stalling engines.

11. Storage battery not adversely affected by very low temperatures.

12. The detector and method of locating nonmetallic land mines.

13. Equipment or methods for removing land mine rapidly from mine fields without injury to equipments or personnel.

14. Methods of rustproofing ferrous metals, which are more durable than present methods, such as bonderizing.

15. Absorbents for carbon monoxide, or catalysts, or other means for oxidation of this gas to render it noninjurious to personnel.

16. Means of defeating darkness to permit vision at night without aid of visible reflected light. (Probably involves an apparatus to translate infrared rays to visible light.)

17. Means of long-distance communication outside the present scope of radio and not restricted by line-of-sight projection.

18. Searchlights which may afford ready means for spreading the beam from narrow high intensity to 15 degrees of greatest intensity practicable.

19. A simple nontoxic process for darkening aluminum and other metals to make them nonreflectant to light.

20. Methods of sabotage by friendly inhabitants within occupied areas.

Suggestions should be submitted to the National Inventors Council, Room 1313, Commerce Building, Washington, D. C., and should comprise a clear description of the proposal with such sketches or drawings as may be necessary.

Fees for Licenses Under Enemy Patents Lowered

The steadily growing demand for licenses under patents seized from enemy and enemy-occupied countries, has led to the reduction of the fee for obtaining such licenses, Alien Property Custodian Leo T. Crowley announced recently. Effective August 1, 1943, the fee will be a flat $15 for each patent instead of $50 for the first patent license and an additional $5 for each related patent.

Advantages to the new terms are that small manufacturers can put single patents to work more promptly, and procedures necessary to release the patents will be simplified since it will no longer be necessary to devote time to determining whether several patents covered by a single application are in a related field. The new fees are also a more equitable compensation for the work involved in searching out contractual agreements that already exist on specific patents.

For more details on the procedure for securing foreign patent licenses see *Electrical Engineering*, June 1943, page 277.

New 30,000-Kw Plant Completed at Fort Peck Dam, Montana

The major part of the power produced at the 30,000-kw-capacity power plant, recently completed by the Corps of Engineers, at Fort Peck Dam, Mont., will be distributed by the Bureau of Reclamation to war industries in Montana and Utah, according to an announcement by Secretary of the Interior Harold I. Ickes.

With the addition of power from the Fort Peck Dam to its system, the Bureau of Reclamation now distributes power from 31 plants with an installed capacity of 1,875,000 kw. The plant at Fort Peck Dam will take an important place in the

Complex Wiring Installed in Radar Sets

These assemblers are installing the intricate wiring in radar sets destined for the use of the United States Navy. The sets are being built at the General Electric Company, Schenectady, N. Y., by men and women who formerly made broadcasting-station transmitters and home receivers, as well as by many thousands of newly trained workers

development of the mineral resources of Utah and Montana for war needs, as practically all of the power developed in these two states is hydroelectric.

JOINT ACTIVITIES

Shock Testing Standard Issued. The American War Standard, "Shock Testing Mechanism for Electrical Indicating Instruments," has recently been released by the American Standards Association. Designed at the request of the War Production Board, with the aid of representatives of industry and the armed services, the mechanism will determine the suitability of delicate electrical indicating instruments for use in mobile and field communications equipment, and other apparatus subject to severe shock. Copies of the new standard are available at ASA headquarters, 29 West 39th Street, New York 18, N. Y., at 25 cents each.

will include the solutions of specific problems in industrial and commercial lighting, as well as the discussion of the general principles of illumination design and methods of calculation. The publication will be under the supervision of a publication committee headed by S. B. Williams (M '37) editor, *Electrical World*, New York, N. Y.

The IES committee on postwar planning is composed of: Ward Harrison (F '36), General Electric Company, Cleveland, Ohio, *chairman;* G. K. Hardacre, Public Service Company of Northern Illinois, Chicago; R. M. Staud, Benjamin Electric Manufacturing Company, Des Plaines, Ill.; E. M. Strong (M '40), Cornell University, Ithaca, N. Y.; and S. B. Williams.

Dudley Medal Awarded; ASTM Officers Announced

Walter Bonsack, chief metallurgist and director of research laboratories, National Smelting Company, was awarded the Charles Dudley medal for 1943 for his paper, "Discussion of the Effect of Minor Alloying Elements on Aluminum Casting Alloys," at the 46th annual meeting of the American Society for Testing Materials held June 28 to July 2, in Pittsburgh, Pa. The medal is awarded annually, in commemoration of the society's first president, for a technical paper of outstanding merit which represents a contribution of original research.

The new officers introduced at the meeting were:

President: Dean Harvey, materials engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Vice-president: J. R. Townsend, materials standards engineer, Bell Telephone Laboratories, Inc., New York, N. Y.

Members of the executive committee: T. A. Boyd, head of the fuel department, General Motors Corporation, Detroit, Mich.; W. H. Finkeldey, Singmaster and Breyer, New York, N. Y.; E. W. McMullen, director of research, Eagle-Picher Lead Company, Cincinnati, Ohio; E. O. Rhodes, technical director, tar and chemical division, Koppers Company; and F. G. Tatnall, manager, testing equipment department, Baldwin Locomotive Works.

OTHER SOCIETIES •

IES Plans Enlarged Postwar Program

On recommendation of its committee on postwar planning, the Illuminating Engineering Society has scheduled two changes in its postwar organization. After the war, a technical secretary, with the general duty of stimulating and facilitating the various technical and research projects carried on under the society's sponsorship, will be employed on a full-time basis. He will work under the executive secretary at headquarters. The IES is also planning publication of a lighting handbook which

Future Meetings of Other Societies

American Chemical Society. September 6–10, 1943, Minneapolis, Minn.

American Institute of Mining and Metallurgical Engineers. Joint fuels conference, October 28–29, 1943, Pittsburgh, Pa. Annual meeting, February 20–24, 1944, New York, N. Y.

American Society for Metals. Annual convention, October 18–22, 1943, Chicago, Ill.

American Society of Mechanical Engineers. Annual Meeting, November 29–December 3, 1943, New York, N. Y.

American Welding Society. 24th annual meeting, week of October 18, 1943, Chicago, Ill.

Association of Iron and Steel Engineers. Annual meeting, September 28–30, 1943, Pittsburgh, Pa.

National Electrical Manufacturers Association. October 25–29, 1943, New York, N. Y.

National Safety Congress and Exposition, October 5–7, 1943, Chicago, Ill.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Kilgore Bill

To the Editor:

Undoubtedly you are familiar with the Kilgore bill (S.702) now pending in the United States Senate. This bill particularly affects all technical men, and I am therefore surprised that no mention of it has been made in *Electrical Engineering*.

Briefly, the bill authorizes the complete socialization of all forms of property, plans, methods and technical information of all industries and all personnel devoted to scientific and technical effort. Under this bill the government could control all scientific and technical personnel, including all persons except physicians and dentists, who have completed college or university studies in any branch of science, or have at least six months training or employment in a technical vocation.

Under this bill the government could acquire exclusive rights in inventions to which the government shall contribute any money, physical facilities, or personnel. This, of course, ignores the constitutional rights of inventors.

All, of course, know that the progress of our country has been due in large part to industrial research and development work. In my opinion the Kilgore bill effectively throttles such work through the removal of any incentive to pioneer new developments.

Finally, we members of technical societies are directly affected since the National Roster of Scientific and Specialized Personnel, to which our names have been furnished by the various societies, could serve as a starting point in socializing technical personnel. We are all glad to do our part in aiding the war effort, which was the reason for establishing such a roster. However, the Kilgore bill is not limited to the length of the war, but specifically provides for the socialization of industry in peacetime.

I believe that the provisions of the Kilgore bill would ultimately cause the disaster of our country. I further believe that it is the duty of the various technical societies as such and their members as individuals to do everything in their power to defeat this bill.

C. M. HINES (A '41)
(Electrical engineer, Westinghouse Airbrake Company, Wilmerding, Pa.)

Editor's Note: The AIEE board of directors recently took action opposing passage of both the Kilgore bill and its House of Representatives counterpart, the Patman bill H.R. 2100. See item in "Institute Activities" section, this issue.

NEW BOOKS • • •

The following new books are among those recently received from the publishers. Books designated ESL are available at the Engineering Societies Library; these and thousands of other technical books may be borrowed from the library by mail by AIEE members. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books. All inquiries relating to the purchase of any book reviewed in these columns should be addressed to the publisher of the book in question.

America's Greatest Inventors. By J. C. Patterson. Thomas Y. Crowell Company, New York, N. Y., 1943. 240 pages, diagrams, 8½ by 5½ inches, cloth, $2. (ESL.)

This book tells briefly the lives and inventions of the 18 men who were selected as America's greatest inventors in connection with the celebration, in 1940, of the sesquicentennial of the United States patent law. The list is an impressive one. The biographies are interesting, accurate, and popular in style.

Analysis of Continuous Frames by Graphical Distribution of Moments. By A. A. Eremin. Apply to author and publisher, A. A. Eremin, 1541—37th Street, Sacramento, Calif., 1943. 17 pages, diagrams, etc., 11 by 8½ inches, paper, $2. (ESL.)

This pamphlet presents a graphical method for the distribution of moments in continuous beams or rigid frames. The method is held to be as exact as algebraic methods and to be much less time consuming. Numerous illustrative examples are given.

ASTM Standards on Plastics. By ASTM committee *D*-20 on plastics; specifications, methods of testing, nomenclature, definitions. American Society for Testing Materials, Philadelphia, Pa., 1943. 375 pages, illustrations, etc., 9 by 6 inches, paper, $2. (ASTM members, $1.50). (ESL.)

The specifications, methods of test, recommended practices, nomenclature, and definitions relating to plastics which have been approved by the society are brought together in one volume for convenience.

Basic Electricity for Communications. By W. H. Timbie. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1943. 603 pages, illustrations, etc., 8½ by 5½ inches, cloth, $3.50. (ESL.)

This is an introductory text for workers in communications and electronics. The book presents the elementary electrical principles that are needed in those fields and applies the principles to concrete practical problems that occur frequently. The text is intended as a course for workers and also as a foundation for advanced study.

Engineering Drawing. By I. N. Carter and H. L. Thompson. 2nd edition. International Textbook Company, Scranton, Pa., 1943. 462 pages, illustrations, etc., 11 by 8½ inches, fabrikoid, $3. (ESL.)

Descriptive geometry and practical engineering drawing are combined in this text. Thus theory and practice are presented simultaneously. Duplication of classroom work is avoided, thus enabling the student to save time.

Engineering Problems Illustrating Mathematics. By J. W. Cell. McGraw-Hill Book Company, New York, N. Y., and London, England, 1943. 172 pages, diagrams, etc., 9½ by 6 inches, cloth, $1.75. (ESL.)

This text contains a collection of problems for students of college algebra, trigonometry, analytical geometry, and differential and integral calculus. It is intended for use in junior and senior engineering courses. By presenting practical problems of technological and industrial application, it aims to give students better understanding of the uses of mathematics than they usually obtain from purely formal exercises. The work is a project of the Society for the Promotion of Engineering Education.

Heating, Ventilating, Air Conditioning Guide, Volume 21. American Society of Heating and Ventilating Engineers, New York, N. Y., 1943. 1160 pages + roll of membership, illustrations, diagrams, etc., 9½ by 6 inches, cloth, $5. (ESL.)

The 1943 edition of this well-known reference book follows the form of preceding ones but has been revised carefully and, in part, rewritten. A chapter on abbreviations, symbols, and standards has been added, and an appendix describes emergency war practices now in use.

Introduction to Atomic Physics. By S. Tolansky with a foreword by Sir L. Bragg. Longmans, Green and Company, London, England, New York, N. Y., and Toronto, Ont., 1942. 343 pages, illustrations, etc., 9 by 5½ inches, cloth, $4.50. (ESL.)

The aim in this book is to supply a broad survey of the development of modern atomic physics for students who have completed a first year of college physics and are proceeding further. The treatment is descriptive and calls for little mathematical knowledge.

Mathematics of Physics and Chemistry. By H. Margenau and G. M. Murphy. D. Van Nostrand Company, New York, N. Y., 1943. 581 pages, diagrams, etc., 9½ by 6 inches, cloth, $6.50. (ESL.)

This book brings together, within a single volume, those parts of advanced mathematics that form the tools of the modern worker in theoretical physics and chemistry. The subjects selected for treatment are those believed to be the most important for such workers, and the subject treatment is full enough for practical purposes.

Principles and Practice of Radio Servicing. By H. J. Hicks. 2nd edition. McGraw-Hill Book Company, New York, N. Y., and London, England, 1943. 391 pages, illustrations, etc., 9½ by 6 inches, cloth, $3.50. (ESL.)

This textbook explains the fundamental principles of radio and discusses their application to the various components of radio receivers. Definite instructions are then given for performing all the more complicated servicing procedures. Test equipment is discussed at length. The new edition has been thoroughly revised.

Rise of the Electrical Industry During the Nineteenth Century. By M. MacLaren. Princeton (N. J.) University Press, 1943. 225 pages, illustrations, 9½ by 6 inches, cloth, $3.75. (ESL.)

This volume presents an interesting, useful, and general account of the early development of all of the principal branches of electrical engineering. The story is told in nontechnical form, but an extensive bibliography is provided for further study. The author, as an engineer actively connected with many electrical developments and as a teacher, writes with first-hand knowledge of much of his field. Pictures of many historic pieces of apparatus are included.

Symposium on Radiography. American Society for Testing Materials, Philadelphia, Pa., 1943. 256 pages, illustrations, etc., 9 by 6 inches, cloth, $4. (to ASTM members, $3.). (ESL.)

This book contains 13 papers presented at a symposium held by the Society in 1943 and re-edited copies of five papers presented at its 1936 symposium. The papers deal with the principles of radiography, various applications to production problems and testing, portable radiographic apparatus, and other practical matters.

PAMPHLETS • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Recent Price Interpretations Number 23. Price Legal Co-ordination Branch, Office of Price Administration, Washington, D. C., 1943. 22 pages; persons will be placed upon mailing list upon request.

Operating Guide for Single Retort Stokers. Department 7-N-20, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., 1943. 42 pages.

Typical Electric Bills, Cities of 50,000 Population and More. Federal Power Commission, Washington, D. C., 1943. 41 pages, 10 cents.

Spreading the Work. Smaller War Plants Corporation, H. O. L. C. Building, 1st and Indiana Avenue, Washington, D. C., 1943.

Manpower. Research Institute of America, 292 Madison Avenue, New York, N. Y., 1943. 92 pages.

Radiant Heat Drying Lamps. Westinghouse Lamp Division, Bloomfield, N. J., 1943. 12 pages

TRANSACTIONS SECTION

Preprint of Corresponding Pages From the Current Annual AIEE Transactions Volume

Any discussion of these papers will appear in the December 1943 Supplement to Electrical Engineering—Transactions Section

Pilot-Wire Relaying on a Metropolitan System

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A NUMBER of papers have been written which discuss individual pilot-wire relaying schemes. A recent paper presented by the relay subcommittee of the committee on protective devices[1] analyzed the pilot-wire circuit used in these relaying schemes. The present paper is a discussion of pilot-wire systems on a large metropolitan system where they have been in successful use for many years. The paper brings out the fact that pilot-wire relaying has many advantages over other forms of relaying because of selectivity and high-speed operation. It has also been found that the reliability of a complete relaying scheme is substantially better than would be expected from the record of the pilot-wire circuit as reported in the subcommittee paper at the 1943 winter technical meeting.

The general use of pilot-wire relaying on the metropolitan system referred to was necessitated by some special characteristics of this system. The system has a large amount of generating capacity closely interconnected through short transmission lines. Therefore, phase isolation is used to reduce the short-circuit duty on circuit breakers and limit physical damage from faults. This isolated phase system includes the use of neutral resistors which limit the ground fault current to such low values that the tripping time would be too slow with conventional overcurrent relaying schemes. The use of pilot-wire relaying permits accurate selectivity with these low fault currents regardless of the switching arrangements of the transmission lines for various operating conditions.

Practically all of the large industrial customers are served by cable loops out of stations or substations. The large number of customers served by a single loop would require excessive time settings on overcurrent relays. Therefore, pilot-wire relaying was selected to permit an indefinite number of steps without increasing the relay timing. Figure 1 shows the gain in relay time obtained by the use of pilot wires on the loop system. The overcurrent relays at the substation end of the loop (see Figure 1*b*) provide back-up protection; those shown in the center section provide primary protection for this section and at the same time limit outages caused by back-up operations to one half the loop.

On this power system, where large amounts of power are transmitted over relatively short distances, the transmission lines are of unusually low impedance. For this reason the use of distance relays is not feasible. The shortness of the transmission lines also favors pilot wires because the cost of pilot wire between stations, when added to the cost of relays at the terminals, results in a total cost for relaying comparable with the cost of distance or directional relays.

The paper includes an economic comparison to indicate that for reasonably short transmission lines, pilot-wire relaying is more economical than carrier relaying in addition to having inherently simpler methods of obtaining selectivity.

Description of Relaying Systems

At the present, a number of different pilot-wire schemes are available for transmission-line protection.[2,4,5,6] These schemes vary considerably in method, some using a direct comparison of currents at the two ends of the line, while others use a derived d-c pulse to effect the comparison. This paper describes only those pilot-wire schemes which are being used on the power system under consideration. The first published reference to these schemes, one of which has been used on this power system for the last 30 years, is a paper by R. F. Schuchardt in 1917.[7] These are circulating current schemes in which alternating current flows through the pilot wires. While all installations are of the same general type, they can be classified in the following two groups:

Scheme 1 (Figure 2) is used on transmission lines consisting of three-conductor underground cable and operates for ground faults only. Under normal conditions, there is no residual current in the line with the result that there is no current in the pilot wires. Upon the occurrence of an external ground fault, current flows through the pilot wires, but the circuit is so devised that in each relay the currents in the two coils will be equal and opposite, with the result that the relays will not operate on an external fault. For an internal ground fault, the current through the two coils of each relay will not balance, and the relay will operate. A description of the current flow for external and internal faults is given in the appendix. The relays used on this scheme are simple two-coil balanced differential relays which require $1^1/_2$ amperes difference in current to operate and trip in approximately two cycles. On most lines to which this system is applied, the current setting corresponds to a primary fault current which is lower than the full load current of the line. Recently, a new telephone-type relay was developed for this system which operates in one cycle with the same current setting.

Scheme 2 (Figure 3) is similar in principle to the first scheme except that a special pilot transformer is used instead of a two-coil relay. By the use of four pilot wires and three sets of terminal equipment as shown, the scheme protects for all types of phase

Paper 43-79, recommended by the AIEE committee on protective devices for presentation at the AIEE national technical meeting, Cleveland, Ohio, June 21–25, 1943. Manuscript submitted April 8, 1943; made available for printing May 5, 1943.

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The authors wish to thank C. W. Selpien, F. O. Wollaston, and others who furnished valued information and criticism in the preparation of this paper.

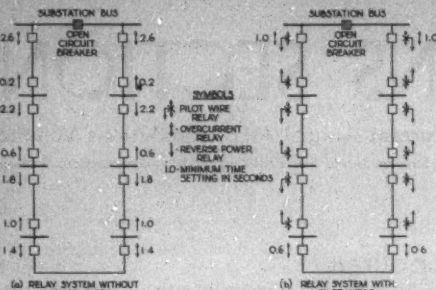

Figure 1. Effect of pilot-wire relaying in reducing relay time settings on a loop transmission system

and ground faults. The special transformer serves two purposes: first, the differential current is obtained from the transformer and, second, the current supplied to the relay is stepped up in value by the transformer. This special transformer makes possible the use of standard overcurrent relays and also results in a lower burden on the main current transformers, since a smaller value of current can be circulated through the pilot wires. This scheme is used on high-voltage lines consisting of single conductor underground cables and operates for all types of phase and ground faults. The high-voltage lines on which this scheme is used are considerably longer than the lines protected by scheme 1. This situation made it advisable to reduce the burden on the current transformers, and the special transformers were developed for this purpose. Most of these relay installations are set to operate at 0.7 ampere which corresponds to a primary fault current below full load current for the line. The latest installations of this system use high-speed relays operating in one cycle. The flow of current in the pilot wires is not shown for this scheme, but it is similar to that shown for scheme 1 in the appendix. It will be noted that the resistors used for this scheme are one half the value used in scheme 1. This is necessary because the circulating current must pass through two resistors in series at each terminal for all types of faults.

While the two schemes shown are the basic ones employed, a modification has been adopted to make possible the use of the two-wire scheme to protect for all types of faults. The method by which this is accomplished is shown in Figure 4. This method is applicable both for scheme 1 and also a two-wire scheme using pilot transformers. The principle advantage of using four pilot wires and three relays instead of two pilot wires and one relay is that the relay target will identify which cable has failed in a transmission line using single-conductor cables. The modified scheme is used to protect three-conductor cables on tie lines between important substations.

For scheme 1, which requires two pilot wires, three-conductor, number 12 pilot-wire cable is used. This is lead-covered underground cable with $^{3}/_{64}$-inch rubber insulation rated at 500 volts. All new pilot cables are tested at 3,000 volts, alternating current, for one minute. The third wire in this cable is a spare and is used in routine testing of the relays. For scheme 2, four wires are needed and five-conductor, number 12 cable is used of the same type as used for scheme 1.

It is interesting to note that in all the schemes described the relay operation is independent of the source of fault current. Relay operation is the same whether the total fault current comes from either end or from both ends. The relay operating currents at both ends of the line are equal and are a direct function of the total primary fault current. This condition holds even for the line open at one end.

A scheme was developed for neutralizing the effect of the capacitance of the pilot wires, but it has not been necessary to apply the scheme for this company. The longest line to which the relay system is now being applied has a length of approximately 15 miles, and even for this line the capacitance of the pilot wires has no appreciable effect. Charging current of the main transmission line inherently appears as fault current to the relay system, and with long, underground, high-voltage cables this factor is of some importance. For the long line previously mentioned it was found necessary to use a one-ampere setting of the relay instead of 0.7 ampere used on shorter lines.

Another characteristic of the schemes described is that it is desirable to use similar terminal equipment at both ends of a line. Correct operation of the system depends on a definite division of the secondary currents, which, in turn, depends on the relative impedance of the terminal equipment. The use of dissimilar terminal equipment might result in a loss of sensitiveness, or the possibility of tripping on through faults.

Obviously, all of the schemes described depend on the pilot circuit being in sound condition for correct operation. Either an open circuit in the pilot wires or multiple grounds on these wires will result generally in incorrect operation. For the schemes which operate for phase faults, trouble in the pilot wires will result in tripping the line on heavy load currents when there is no fault. This is not serious since it results in only one outage in a group of lines. For the schemes limited to operation on ground faults, trouble in the pilot wires will result in tripping of the line for an external fault. In all schemes, the special case of a short-circuit between pilot wires near the center of the line will prevent tripping for an internal fault on the power line.

In recent years, the pilot-wire systems have been used to protect lines which are directly connected to transformers without a primary circuit breaker. The method employed is to use the pilot-wire system to protect the high-voltage line, and standard percentage relays to protect the transformer. The operation of the transformer relay open-circuits the pilot wire with the result that the line breakers at the far end of the line will open for a small value of fault current.

This principle is also employed in some cases to trip the far end of a tie line between important substations. The location of the current transformers used in the pilot-wire scheme is such that the zone of protection of the pilot-wire relay does not cover all the terminal equipment of the line. In many cases a fault-bus or overcurrent relay is available which protects the equipment not covered by the pilot-wire relays. In these cases, the operation of the fault-bus or overcurrent relay unbalances the pilot-wire system,

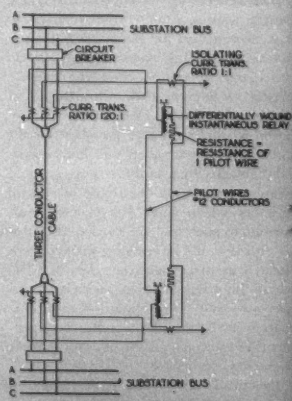

Figure 2. Scheme using two pilot wires and protecting for ground faults only

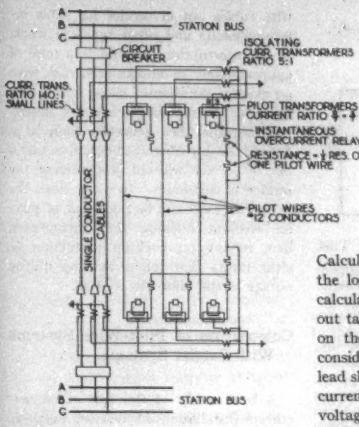

Figure 3. Scheme using four pilot wires and protecting for all types of faults

thereby causing the far end of the line to be tripped.

Abnormal Voltages on Pilot Wires

As shown in Figures 2 and 3, the pilot-wire systems are isolated from all ground connections. With this arrangement, one ground on the relay system will not cause an operation of the relays. Also, the longitudinal induced voltage on an unfaulted pilot cable is so distributed that at each end of the cable one half of the total induced voltage is impressed from conductor to sheath.

In general terms, the longitudinal induced voltage is a voltage induced along a conductor, which builds up a voltage between the conductor and ground. In the underground power system being discussed in this paper, the longitudinal voltage induced under fault conditions has a somewhat different character. In this system practically all the current in a ground fault returns to the source over the lead sheaths in the duct run carrying the faulted cable. The sheath of the pilot cable is connected to the sheaths of the power cables at each manhole, and the entire group of sheaths is practically at ground potential throughout its length.

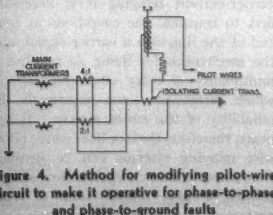

Figure 4. Method for modifying pilot-wire circuit to make it operative for phase-to-phase and phase-to-ground faults

Calculations and tests have shown that the longitudinal induced voltage can be calculated with sufficient accuracy without taking into account the flux linkages on the pilot cable. It is necessary to consider only the resistance drop in the lead sheaths caused by the return of fault current on this sheath. The longitudinal voltage in this case is the difference of potential between the two ends of the pilot-cable sheath. Also, it is the voltage that would appear between conductor and sheath at one end of the cable if the conductor were connected to the sheath at the other end. As noted previously, if the pilot-cable insulation is in good condition, one half of the longitudinal voltage would appear between the conductor and sheath at each end of the cable.

All terminal equipment of the relay system is tested at 1,500 volts a-c for one minute, when placed in operation. The isolating current transformers are tested at 2,500 volts a-c for one minute. As previously noted, new pilot cable is tested at 3,000 volts a-c for one minute.

The low values of ground-fault currents which are obtained in this power system, combined with the fact that all transmission lines and pilot wires are in lead-covered underground cable, result in very low values of induced voltage on the pilot-wire system. Calculations and tests have shown that on practically all lines the maximum induced longitudinal voltage is considerably less than 1,000 volts. For about five per cent of the transmission lines, the induced voltage is above 1,000 volts, and in the maximum case there are approximately 2,500 volts induced. However, even in this maximum case, the effect of operating pilot wires ungrounded results in the voltage stress on the pilot wires and terminal equipment being within their insulation strength.

In many cases, the rise of ground bus potential under fault conditions, caused by high grounding resistance, creates a problem in the protection of pilot-wire systems.[2] However, on this power system this effect is practically negligible. As stated before, most of the fault current returns to the station over lead sheaths, which, in turn, are directly connected to the ground bus at the station. This arrangement, combined with the fact that the total ground fault current is relatively small, results in extremely low values of ground bus voltages in the station supplying the fault current.

As a result of the low values of induced voltage on the pilot-wire cables, it has not been found necessary to use any equipment on the cables to protect against transient overvoltages.

Comparison of Privately Owned and Leased Pilot-Wire Circuits

One important question that always arises in the application of pilot-wire relays is the use of privately owned pilot wires versus leased telephone wires. Privately owned circuits are relatively high in cost; on the power system under consideration, the pilot cables used cost up to approximately $1,500 per mile installed. No cost for ducts is included in this figure because pilot cables are generally installed in center ducts which do not have good heat-radiating capacity for power cables. This cost for privately owned circuits compares with a cost for leased wires of approximately $60 per mile per year, in the metropolitan area.

Privately owned wires have several operating advantages. They make possible the use of lower resistance wires which are preferable for the circulating current schemes described in this paper. Also private cables are of higher insulation strength and, therefore, are less susceptible to the effects of induced voltage. These circuits are better protected from external damage and their service records show the benefits gained. Over a period of ten years, on this power system, there have been only five service failures on 218 circuits, consisting of approximately 300 miles of cable. This power system uses leased telephone wires on a telemetering system which consists of approximately 120 circuit miles. In a two-year period

Table I

Relay System	Per Cent Incorrect Operations	Remarks
All classes	3.7	Majority of relays, simple induction type
Used on high-voltage system	7.2	Includes many of the more complicated types
Pilot-wire schemes	3.7	Speed of operation faster than other relays on high-voltage system, in many instances

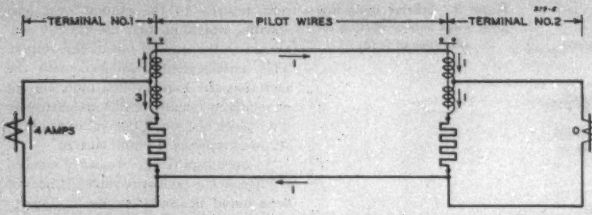

Figure 5. Current flow for internal fault with all fault current supplied from terminal 1

there have been eight emergency outages on this system, the duration ranging from a few minutes to five hours.

Data on Operating Record of Pilot-Wire Circuits

The number of pilot-wire circuits now in use on the power system under consideration, are as follows:

Scheme 1	155 circuits
Scheme 2	25 circuits
Modified scheme 1	38 circuits
Total	218 circuits

The total length of cable involved on these circuits is approximately 300 miles. During the last ten years there have been 164 operations of the pilot-wire relay systems, of which six have been incorrect. Of the six cases of incorrect operation, one was caused by terminal equipment and five by trouble on pilot cables. Following is a detailed analysis of these six incorrect operations:

In one case a terminal resistor was damaged by overloading during the testing of the relay system. As a result of this damage, the resistor was open-circuited and the line tripped out on a through fault.

In one case a pilot cable was cut by mistake by an employe of another company, and the line opened on load current. In the process of locating the trouble in this pilot cable, a company employe cut another pilot cable by mistake with the result that a second line opened on load current.

In one case a street lighting circuit failed and caused the burning of a pilot cable, which caused an opening of the transmission line.

In two cases a pilot cable was damaged and the conductors became short-circuited, with the result that the lines tripped on through faults.

In all cases of incorrect operation, the lines were tripped out either on load current or on external faults. In the cases where the line tripped on load current, service was not affected because the line which was tripped out was only one of a number operating in parallel. This situation also applies to those cases where a line tripped on through fault. Therefore, none of the incorrect operations resulted in service interruptions.

The high degree of reliability of the pilot wires has made it unnecessary to use any form of continuous supervision to check the continuity of the wires. The wires are checked semiannually as part of the routine relay test.

A comparison of results obtained by different methods of relaying requires consideration of the relay speed necessary on the different parts of the system. On this power system, the largest number of line relays is on the intermediate voltage transmission system where lines are short, stability is not a factor, and a simple time selection scheme is satisfactory. On the high-voltage system, including all lines in the interconnected group, the power concentration is greater and stability is a factor on the long overhead lines. For this high-voltage system, high-speed relaying is essential, and modern distance and carrier relays are being used in these installations.

Table I is a comparative record to show relay performance on this metropolitan system over a ten-year period.

In addition to the service outages referred to there are a relatively large number of planned interruptions of the pilot-wire systems. These outages are occasioned by the necessity for taking pilot-wire cables out of service for cable rearrangements and other types of work. These interruptions amount to a total of approximately 75 outages each year, with an average duration of about four hours. However, these outages are not important because they generally come at a time of the day when the line can be taken out of service without jeopardizing the service to customers. In many cases the pilot-wire cable can be taken out of service without opening the transmission line, relying on back-up protection to clear faults that might develop during outage of the pilot-wire system.

Comparison of Pilot-Wire Systems With Carrier Systems

A brief study of the cost of carrier-current installations for relaying purposes shows that using the type of system described in this paper, pilot-wire systems are competitive in cost for lines up to approximately 20 miles in length. Using telephone wires, the pilot-wire system is competitive with carrier current up to lines of approximately 35 miles in length. The cost comparison definitely favors carrier-current relaying on longer overhead transmission lines.

Pilot-wire relaying of the type described in this paper is inherently simpler than the carrier-current systems now in use. In the pilot-wire system the comparison of conditions at the two ends of a transmission line is made directly, whereas in the case of the carrier-current relaying, the comparison is an indirect one. In carrier-current relaying it is necessary first to translate the conditions at each end of the line into a carrier signal, and the mechanism for doing so requires a multiplicity of relay elements, each of which introduces some hazard to the reliability of the entire system. It appears, therefore, that for lines where pilot-wire relaying systems can be justified from an economic viewpoint, they should provide a more reliable form of relay protection than carrier-current relaying.

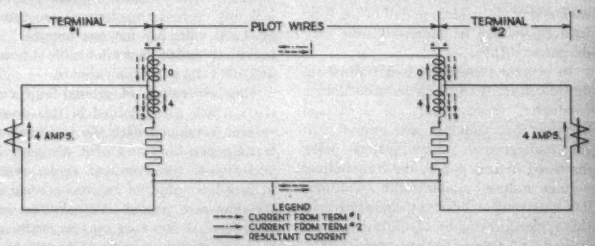

Figure 6. Current flow for internal fault with equal currents supplied from the two terminals

Conclusion

Pilot-wire relaying is applicable over a substantial field in transmisson-line protection. This scheme provides high speed and selective operation under all switching arrangements. There are many types of pilot-wire-relaying schemes which have been developed over the past 30 years. Only the schemes with which the authors have had operating experience are discussed in this paper.

Induced voltage is one of the most commonly discussed limitations to pilot-wire-relaying schemes. On overhead systems special precautions must be taken, but for this metropolitan system where both transmission lines and pilot wire are underground induced voltages have caused no trouble.

On this metropolitan system the percentage of correct operations, over the past ten years, is approximately the same as obtained from the very simple induction relay schemes. On the other hand, the percentage of correct operations is appreciably higher than that obtained from the more complicated schemes, including high-speed distance relays and carrier relays which are required for modern high-speed switching.

Pilot relaying is more economical than other schemes on relatively short transmission lines. Where pilot wires are usable, they are inherently more simple than other relays with comparable operating speed.

Appendix

Figures 5, 6, and 7 show the flow of current in the pilot wires and relay coils for external and internal fault conditions. These diagrams are based on scheme 1, but the same principles apply to the other schemes.

In Figure 5 an internal fault is assumed with all current being supplied from one end of the line. The primary fault current is assumed to be of such a magnitude that the current in the secondary circuit of the isolating current transformer is four amperes. This current divides at the point where the isolating current transformer connects to the relay coils, in proportion to the impedance of the two paths. Three amperes flow into the coil connected to the resistor and one ampere to the coil connected directly to the pilot wire. The current of one ampere flows through the pilot wire, through the two relay coils at the far end of the line, and back to the first terminal over the other pilot wire. This three to one division of current between the two coils is the same for all conditions and in all the schemes described. The ratio of the two currents is fixed by the value of the resistor in the circuit at each terminal, which in the case of the two-wire scheme is equal to the resistance of one pilot wire. With the value of the fault current chosen, the vector sum of currents in each relay for the case of Figure 5 is two amperes. Since the relays are set to operate at a net current of $1^1/_2$ amperes, this fault current is sufficient to trip both relays. Note that the resultant current at the two terminals is identical, although the fault is fed from one end only.

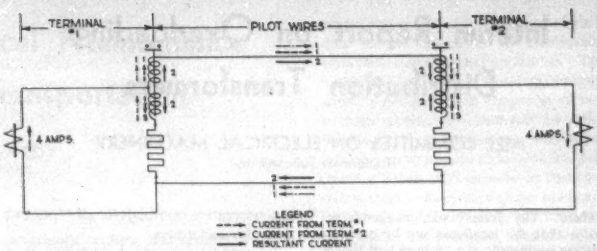

Figure 7. Current flow for external fault

In Figure 6 an internal fault is again assumed, but, in this case, there is a current of four amperes supplied from each end of the line. The simplest method of analyzing the flow of current in the pilot-wire system is to use the principle of superposition. The diagram shows separately the flow of current supplied from each end of the line. The division of current at the point where the isolating current transformer connects to the relay coils is based on the same principle covered in Figure 5; that is, three fourths of the current flows in the relay connected to the resistor and one fourth to the coil connected directly to the pilot wire. This diagram also shows the resultant of the two circulating currents, which is the actual current flowing in the system. It will be noted that the resultant differential current in each relay is four amperes instead of two as in the previous case. This illustrates the general principle that the net current in each relay is a direct function of the total internal fault current. In this specific case of equal currents fed from the two ends of the line, the pilot-wire current is zero. This condition holds only for this specific division of fault current.

Figure 7 shows the condition for an external fault with the magnitude of the current equal to four amperes in the isolating current-transformer circuit. Again, this diagram uses the principle of superposition to show the flow of current. It will be noted that the flow of current from terminal 1 has the same magnitude and direction as for the case shown in Figure 6. For the current from terminal 2 the current has the same magnitude but is opposite in direction because of the through-fault condition. The effect of this reversal of direction is to give equal and opposite currents in the two relay coils. This illustrates the general principle that for a through fault of any magnitude the currents in the relay coils will be equal and opposite, with the result that there is no tendency for the relay to operate on such faults.

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Interim Report on Overloading Distribution Transformers

AIEE COMMITTEE ON ELECTRICAL MACHINERY
Transformer Subcommittee

Preface: The present war emergency requires that the maximum use be made of existing equipment and systems and that a minimum of critical material be used for new equipment.

This publication, as well as other guides and reports in this series, has been prepared for the information of users during the war emergency. Upon termination of the war emergency, they will be reconsidered by the standards committee and the committees that prepared them, and will be approved, revised for normal use, or rescinded.

This procedure is being followed in preference to the preparation of special emergency standards which might involve redesigning and drastic changes in manufacturing practices. These guides will accomplish the maximum conservation of critical materials, since they provide for the maximum use of existing equipment and systems, as well as new equipment, without changing the fundamental basis on which the present standards have been prepared.

THE "Interim Report on Guides for Overloading Transformers and Voltage Regulators," which was presented at the AIEE summer convention, June 22, 1942, and was published in the September 1942 issue of ELECTRICAL ENGINEERING, gave information on the overloading of all types of transformers and of voltage regulators.

The interim report gave basic principles to be followed for determining permissible overloads with normal life expectancy based on the assumption that the transformer would be operated continuously throughout its life on the basis of the assumed conditions. It also gave tables and charts covering permissible emergency overloads with moderate sacrifice of life expectancy. The data given result in conservative overloads for all types and sizes of transformers.

It must be recognized, however, that such overloads may be too conservative for some small distribution transformers where the temperature rise is appreciably lower than the specified rise on account of the use of a tank larger than necessary for thermal requirements, because general rules and tables such as those given in the "Interim Report on Guides for Overloading Transformers and Voltage Regulators" must be made to fit transformers of all kinds, varieties, and sizes (within certain limits) having different design characteristics.

It is difficult to fix specific limitations for operation of distribution transformers because of the multiplicity of factors governing such operation.

For distribution applications the shape of the load curve imposed upon a transformer will vary for each application. Although for larger-sized distribution transformers the load curve may be comparable to that for a complete distribution system, for the smaller units, such as used on residential and commercial applications, the load curves are usually very complex and are not classified so readily in terms of load factor as are the load curves for power transformers.

The thermal characteristics of distribution transformers also are affected by numerous factors. Small distribution transformers inherently have greater cooling ability per kilovolt-ampere than larger sizes with the result that they have greater thermal ability. In addition, the particular design has greater influence on the permissible load than any other factor being considered. The establishment of thermal characteristics for each size, type, and manufacture of unit would be a tremendous task.

In distribution transformer application, consideration must always be given to permissible voltage drop and voltage variation in the transformers and the rest of the system as well as to the thermal characteristics of the transformers. In some cases, voltage drop rather than thermal capacity may be the limiting factor in the loading of distribution transformers.

While it would be desirable to have recommendations that would more nearly cover the ultimate load capabilities of these smaller units, specific recommendations must depend on factors peculiar to individual systems and loads to such extent that it seems impractical to produce data that can be applied generally.

The overloads for transformers recommended in the "American Standards for Transformers, Regulators, and Reactors, *C*-57.3" and in the "Interim Report on Guides for Overloading Transformers and Voltage Regulators" are based on actual load values. Various methods of estimating loads on distribution transformers are in common use. These methods do not always give results on a basis comparable to the actual load values given in the afore-mentioned reports.

It seems necessary, therefore, that those users seeking the near ultimate in loading of distribution transformers base their thoughts and conclusions on the particular characteristics of the equipment and loads peculiar to their own systems. They will find some assistance in the guide and report referred to previously and in the papers listed in the references.

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Personnel of transformer subcommittee: M. S. Oldacre, *chairman*; F. S. Brown, E. S. Bundy, represented by R. T. Henry; J. E. Clem, I. W. Gross, V. M. Montsinger, J. R. North, W. C. Sealey, F. J. Vogel, C. F. Wagner.

This interim report was prepared by the AIEE transformer subcommittee of the committee on electrical machinery for the purpose of making essential information immediately available to war industries, thus furthering the conservation of valuable material for the war emergency. It is educational and in no way mandatory. It is not intended as a "Standard," and has not been approved formally by the standards committee nor the board of directors.

Adequate Electrical Maintenance Essential to Transportation

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Synopsis: The demand for public transportation is increasing rapidly under present conditions of accelerated industrial activity. Adequate maintenance of electrical apparatus on rolling stock is essential to avoid impairment to the war effort. Measures which will assist to retain generators, motors, and control in service practically 100 per cent of the time are proper operation, effective inspection, preventive maintenance, keeping apparatus clean, accurate adjustments, prompt worn-part replacements, undelayed commutator conditioning, use of improved insulation, and correct lubrication. More careful attention to all of these factors during the present emergency will assure maximum rolling stock availability.

Maintenance of Transportation Electrical Apparatus and the War Effort

AMERICANS are confirmed optimists. They like to believe that life, somehow, works out for their individual good. But today, we are faced with a transportation situation which can ruin our entire internal economy just as surely as being bombed to destruction. Goods and people must be moved to places where they are needed to be effective in the war effort. Electric locomotives, suburban cars, rapid transit trains, streetcars, trolley coaches, and Diesel-electric buses are doing their bit in meeting this demand. The adequate maintenance of electrical apparatus on this rolling stock is a vital factor in providing the necessary supply of war materials.

Armies and navies are useless without the tools of battle. Materials and workers must be moved to and from industrial plants to produce these tools. The need for maximum productive capacity makes such transportation essential to the war effort. The "maintenance front" for generators, motors, and control on locomotives, cars, and coaches must be one that utilizes all available facilities expeditiously. There can be no overestimating the importance of this action or the seriousness of the situation. The maintenance of electrical apparatus on rolling stock requires planning, supervision, and execution that will assure continuity of service from every piece of equipment available.

Adequate Maintenance Needed

The steadily mounting demand for transportation has produced an acute condition, both on the city transit systems and the railroads. The total number of passengers handled by city properties in 1942 was 24 per cent above the figure for the year 1941. In the case of the railroads, passenger traffic attained an all-time record as measured by passenger miles. In 1942 (11 months) the increase was 80 per cent in comparison with a like period in 1941. A corresponding figure for the step-up in freight ton-miles is 35 per cent above the previous year. The allocations of material to build new locomotives, cars, and coaches are far below needs, and this demands maintenance standards that establish maximum availability for all existing rolling stock.

The loss of trained personnel to the armed forces and war industries contributes to the difficulties of maintaining transportation electrical apparatus. This is reflected in improper handling of equipment as well as lack of knowledge of how to make repairs. The necessity for utilizing operators and enginemen who fail to measure up to normal standards has produced a substantial increase in damaged rolling stock. Also, the number of experienced shop men is reduced, which further complicates the problem. Turnover has been stepped up, and more time is required for training new employees.

The lack of a sufficient supply of rolling stock and the constantly increasing traffic demands have established a definite need for adequate maintenance. The condition is made more serious by the decrease in the number of skilled workmen. A demand has been created for more effective planning and more dependable maintenance practices. The problem is one requiring ingenuity and resourcefulness to assure a reasonable measure of success in meeting an extremely difficult situation.

Providing Effective Electrical Maintenance

The demand for adequate generator, motor, and control maintenance requires improvements in supervision. There must be better administration and direction in order that the available man power can be used to the best advantage. It is the duty of the supervisory forces to ascertain how to get a better job done with an expenditure of the same or fewer man-hours. The time which is saved by doing a job in a more simple manner is worth as much, if not more, than if it is secured by making additions to the working force. Supervisory planning is useful as a means to avoid abusive operation of rolling stock, provide effective inspection procedures, and make full utilization of preventive maintenance.

The attainment of efficient execution of maintenance procedures, once they are established, is vital under present wartime conditions. The limited supply of rolling stock, maintenance parts, and man-hours makes it imperative that there be no waste. Those who direct the activities must follow all work closely and see that it is done in a manner conforming to practices which produce the best results. This requires a broader knowledge of progress in the industry and more attention to details than has been customary in the past. Some of the measures which are productive are keeping apparatus clean to improve operation, making accurate adjustments to insure correct

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functioning, replacing worn parts immediately to prevent possible failures, conditioning commutators promptly to avoid major repairs, using improved insulating materials to prolong the life of windings, and providing correct lubrication to assure greater dependability.

Proper Operation

Abusive operation of rolling stock should be avoided since the ultimate result is lowering the standard of service provided. A schedule may be completed and a job done at the time the damage occurs, but the loss on some future occasion is likely to be many times the immediate gain. Safety can be a justification of emergency handling, or a "net" contribution to the war effort may warrant such action.

On one city property, motor failures during the severe weather of the past winter resulted in the operation of as much as 5 per cent of the equipment with three motors instead of four. A three-motor car is overloaded and the machine operating alone severely punished. The ultimate result is an increase in total failures and the number of cars out of service. Perhaps a long-range plan to use higher-grade repair materials would avoid this situation—a procedure which is proving effective on many city transit systems.

Another burden on the maintenance personnel is a substantial increase in damaged rolling stock. This is particularly true on city properties where it has been necessary to make use of many inexperienced operators. A similar condition exists in locomotive operation because of such practices as overloading Diesel-electric engines by hauling heavy tonnages at low speeds, damaging motors on switcher engines by exceeding maximum safe-speed limits, holding on grades with power on, leaving partial power on the motors after making stops, and bringing trains in with motive power partly inoperative. The trend in damaged generators, motors, and control is upward at a time when every piece of rolling stock is needed. This is a supervisory problem—one where co-operation between mechanical and transportation or operating departments has demonstrated its value in securing maximum use of coaches, cars, and locomotives.

Effective Inspection

Regularity of inspection is a definite benefit in reducing failures and lowers the over all man-hours required for maintenance work. Road failures frequently prove costly, and measures to eliminate them are essential. Too frequent attention is often as unsatisfactory as neglect. In the former case, an excessive amount of "tinkering" produces trouble, and it is better to let the apparatus alone until attention is known to be needed. One procedure under present emergency conditions is to do more "looking" and less work. However, the examination must be by men experienced in detecting possible sources of trouble.

Figure 1. Electrically propelled transportation rolling stock which must be kept running to assist in the war effort

Results indicate that inspection offers an opportunity for supervisory studies to adjust frequency to the exact requirements of the particular location and equipment. Naturally, there is considerable variation in needs, and schedules are fixed by items requiring the most frequent attention. Consideration of each part to determine its operating time without attention will disclose if this can be made longer. Inspection of routine items may be extended, provided the condemning limit is reached after the next scheduled examination. Changes in design to extend the inspection time of parts which establish limitations have proved helpful.

Definite inspection plans are employed which divide the work into classes based on frequency. The use of a central location for all rolling stock has demonstrated its advantages. Various jobs are specialized, and, with men trained for specific duties, man-hour requirements are lowered. Also, the provision of tools to operate on a "production-line" basis decreases the time for each job. Check lists are beneficial in securing complete coverage. Each man must know his duties, and a check list gives the details of what is required. Such lists can be worked out for individual properties to meet the needs of the equipment operated.

Preventive Maintenance

Preventive maintenance—making replacements or repairs before defects occur—has been utilized with excellent results. A part of such a program that has proved advantageous is the exact determination of the cause of failures to avoid repeaters. For example, a generator or motor may break down because of a weakness within the machine, a defect in the control, or an improper operating condition. The same may be true of a control failure. If the defect is outside the particular piece of apparatus that is injured and remains undiscovered, replacement of the damaged part is almost certain to result in a recurrence of the trouble. This happens frequently on many properties and is chargeable to inadequate maintenance.

Experience has demonstrated that "repeaters" can be eliminated. An effective system on one city property is the provision of a staff of assistant equipment engineers under the direction of the equipment engineer. Definite apparatus assignments are made, and it is the duty of each assistant equipment engineer to follow continually all items under his jurisdiction. When failures occur, or

Figure 2. Checking the length of traction motor brushes

wear appears abnormal for a particular part, it is investigated and recommendations made to eliminate weaknesses that may exist. Exceptional freedom from trouble has been attained on this property.

Overhauls constitute the backbone of preventive maintenance. Under the present difficult conditions there is a decided tendency to neglect this work. Such a procedure will ultimately lead to a breakdown on the transportation system and require "heroic" measures to reestablish satisfactory operation. Results have shown that overhauls in accord with a regular schedule are essential, and they must be complete.

Keeping Apparatus Clean

Dirt can be defined as material which is foreign to any part of a piece of electrical apparatus. For example, oil or grease are classified as dirt when they are on cables, windings, and commutators. Dust particles constantly are forming a blanket over windings and confining the heat. Dust accumulates between motor fields, plugs up armature ventilating ducts, enters armature slots, and reduces V-ring creepage distances. It serves as an abrasive on commutators and in brush boxes. Its spongelike nature permits soaking up harmful fumes, moisture, oil, and acid, thus bringing them in proximity to windings. It clogs controller cams, interferes with relay operation, causes interlock misfunctioning, and contaminates oil.

As a result of the presence of dirt, motors are overloaded, throw solder, become grounded, and require rewinding. Brushes stick in brushholders, brush spring action is impaired and commutators damaged. The reduction of creepage distances causes grounds and flashing, thus leading to failures. The dust blanket overheats control coils, damages bearing surfaces, causes relays in interlocks to misfunction, impairs cylinder operation on pneumatic switches, and clogs magnet valves. Dirt in bearing lubricant is certain to result in short bearing life.

Experience shows that keeping motors and control clean is insurance of increased availability. Man-hours are saved by care and attention to a regular cleaning schedule for removal of dirt before trouble occurs. Compressed air is used for this purpose, but care should be taken that it is dry and contains no foreign material. Exposed surfaces can be wiped with clean dry cloths after compressed air is employed. Locating ventilating intakes where clean air is obtainable and applying tight fitting covers to keep dust out of the apparatus has proven helpful. Regular overhaul of motors and control affords an opportunity for much needed thorough cleanings. This is another reason why maintaining the overhaul schedule is essential.

Accurate Adjustments

Checking apparatus to see that adjustments correspond to values that give correct functioning is necessary to secure satisfactory operation. Instruction books and check lists include data indicating what is needed to insure proper performance and avoid failures. The use of gauges wherever practicable gives uniformity and limits the time consumed in making adjustments.

Maintaining brush tension accurately is needed to secure good commutation and can be checked readily with a small spring balance attached to the brush pressure finger. Commutators must be concentric and, when deviation is suspected, can be verified with a dial indicator. Unit switches need to be free from sluggishness when closing. In the case of pneumatic types, cylinder travel is required to meet specific limits and accurate adjustment of magnet valves obtained. Finger pressure on reversers and interlocks must be maintained at recommended values. Correct relay settings, especially for overload and operating currents, contribute to protection and proper functioning. In some cases gauges have been developed for verifying gaps and spring tensions, thus speeding up relay work.

Prompt Worn-Part Replacements

Worn parts demand prompt attention to assure that none are left in service except those which are certain to run until the next inspection. Otherwise, failures in service may occur which often prove costly. The inclusion of condemning limits for various wearing parts in check lists provides a convenient reference for determining when a part should be removed. Such limits are subject to variation for different localities and types of service.

Generator and motor brushes require regular replacement, since they are in constant use. Current collection and mechanical friction cause them to wear out, the life varying with differences in operating conditions. Control parts that have maximum usage and require most frequent renewals are contact tips (main switch, cam switch, and interlock), arc

Figure 3. Method of attaching fixture to grind commutator with armature running in its own bearings

horns, and arc chute sides. There may be occasional worn shunts, damaged resistor units, and, in the case of pneumatic switches, broken cylinder springs.

When abnormal wear of parts occurs, it is an indication that an unsatisfactory condition exists. This is a warning which requires corrective action. Replacement of parts which appear to be possible causes of faults has done much to minimize maintenance work. There are items, such as brushholder boxes, brushholder pins, controller bearings, switch armature shafts, and switch hinge pins that are subject to relatively slow wear. The normal procedure is to make necessary renewals during heavy inspections or when the equipment is overhauled.

Undelayed Commutator Conditioning

The appearance of commutators is an excellent indication of the condition of the complete equipment. Poor commutation is evidence that something is wrong, and the cause may not always be within the machine. The condition is a warning, and it is usually ample since commutators seldom fail suddenly, to ascertain the reason for unsatisfactory performance. Investigation and prompt correction of conditions that produce poor commutation always reduce "maintenance man-hours." It is essential that the surface of commutators be kept smooth and true as this has a direct bearing on their life and that of the brushes. Burned spots may result because of surge currents which flow during short circuits or when power and brakes are applied simultaneously. Such spots cause the brush to leave the commutator momentarily since it is unable to follow the contour as fast as the commutator rotates. Thus, the burned spot becomes progressively worse. It is necessary to smooth the surface and bring the commutator back to concentricity.

Figure 4. Fixture to hold armature firmly in position when assembling bearings and housings

One method of grinding is by means of a rig which is attached to the frame of the machine. A generator or motor is run at slow speed during the operation. When working on a motor the wheels are jacked up and power supplied from a welding generator or the trolley. In the latter case, the motor is brought up to speed by placing the controller on the first notch. Power is then shut off, and the grinding done while the speed drops to a lower value. Light cuts are made to avoid deflection of the rig and impairment of concentricity. A dial indicator serves to check accuracy, and after the operation has been completed, the slots must be cleaned and all dust blown out of the machine. A second method for grinding a commutator with the armature in its own bearings is the provision of a fixture for shop use when the armature is out of the machine. Such devices are easily constructed and support the complete armature with its bearings and enclosures.

Improved Insulation

Insulation (class *B*) is now obtainable made from asbestos, glass textiles, and mica that provides exceptional durability and is far superior to the high-temperature materials of a few years ago. The life of windings is being materially increased by making substitutions for combustible substances (class *A*), thus stepping up heat-resisting characteristics. Advantage is being taken of high-temperature insulation when making repairs to improve the performance of older electrical apparatus. This procedure increases the "capacity margin" and assists in bettering availability at a time when every effort should be made to reduce "repair man-hours."

Dipping and baking of armatures and fields at regularly scheduled intervals prolongs the life of insulation. The frequency of such work is dependent on the conditions existing in the localities where the equipment is operated. For example, there will be differences for cold, hot, wet, and dry climates. Also the dust content of the atmosphere is an important consideration. A check of the condition of the insulated surfaces is the best indication of what is needed.

Improvement in varnishes is another factor having a direct bearing on dipping and baking practices. The heat-setting or heat-reactive synthetic-resin types represent an important development in varnish making. Curing is by heat reaction rather than oxidation as occurs with the oil types. The heat hardening produces an "all through" drying even for thick films and in restricted locations. Some of the characteristics of the varnishes are excellent resistance to moisture, oil, weak acids and alkalies; good dielectric strength; long life; ready penetration; complete drying by baking; tough

Figure 5 (left). Inspecting the accelerator and contactor group of a modern street-car control equipment

Figure 6 (right). Procedure followed in tightening the contact tips of a magnetic contactor

resilient surface film; reasonable curing temperature, and ability to withstand high class *B* temperatures.

The measurement of insulation resistance is a valuable tool for "preventive maintenance" and is usable to save many service interruptions. It is subject to wide variations, and the factors which influence measurements must be known and viewed in relation to each other. Temperature, moisture, test voltage, and the length of test are the important items to be considered. Standards can be fixed for various pieces of apparatus and measurements taken at regular intervals. When unsatisfactory values are observed, this is a warning that corrective action is needed. The measurement of insulation resistance will also assist in determining dipping and baking frequency.

Correct Lubrication

Care is required in the selection of the correct lubricant for various pieces of apparatus in order to secure satisfactory results. In the case of waste-packed axle and armature bearings, straight mineral oils appear best. Summer grades are required during hot weather and winter grades when it is cold, the suggested dividing line being 40 degrees Fahrenheit. This assures a more nearly constant rate of feed, since viscosity is the determining factor. Packing must be correct with a vertical wool yarn wick adjacent to the journal or shaft and a tightly filled box to hold the wick in place.

Gears and pinions require special attention to assure proper operation. The lubricant which is used must maintain its consistency and contain no nonlubricating components, have exceptional adhesive properties, be of sufficient body to withstand high tooth contact pressure, have freedom from acids, be applied easily, have enduring qualities and possess noise-deadening characteristics. Possibly the properties of stickiness and load-carrying ability are most important. There is need for the careful selection of summer and winter grades where wide temperature variation occurs.

It has been found that grease does the best job in lubricating antifriction bearings. Occasionally such bearings are allowed to run too long without lubrication, but more often the attention received is too frequent. The result of overgreasing is an increase in the operating temperature. Tolerances are exceptionally close and are comparable with those in fine time pieces. Bearings must be kept clean, since dirt means damage. When greasing, take precautions to keep the cover on the grease can, use a clean instrument to remove grease from the can, and avoid overgreasing. Housings should be one-fourth to one-half full. In the case of a new bearing, the housing should be one-third full, but the bearing space should also be filled. A relief or drain plug for use when greasing will prevent the overgreasing danger. It is desirable to apply such plugs on older type bearings when machines are being overhauled.

Lubrication of control apparatus requires restraint in the use of the "oil can." Some pieces of apparatus, such as master controllers, may be equipped with bearings requiring lubrication while others have the oilless type. For example, a typical locomotive controller requires lubrication for the upper and lower bearings of the main drums, the reverse drum bearing, and the main handle bearing pins. On the other hand, the modern street car master controller needs no lubrication. Pneumatic switch cylinders must be oiled, but the hinge pins and armature shafts of magnetic contactors require no lubrication. Strict adherence to instructions which can be included in check lists produces the best results.

Progress in Realizing Adequate Maintenance

The procedures which have been discussed give a general outline of the best means for obtaining intensified use from electrical equipment of transportation rolling stock. Many properties are benefiting from proper operation, effective inspection, preventive maintenance, keeping apparatus clean, accurate adjustments, prompt worn-part replacements, undelayed commutator conditioning, improved insulation, and correct lubrication. The availability of generators, motors, and control is being stepped up in an endeavor to keep pace with the demand. The results are creditable as a contribution to an "all-out" effort to provide essential transportation. There is need for more general use of all factors which improve maintenance efficiency in meeting the present emergency. There may be other profitable ideas which still lie dormant, and it is to be expected that the future will bring further progress.

A New Type of Adjustable-Speed Drive for A-C Systems—II

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Synopsis: The preceding paper of this series[1] presented the theory and principles of operation of a new type of a-c motor and its control circuit. This system of speed control has the advantage of being economical from the standpoints of initial cost, efficiency of operation, and ability to correct power factor. However, these advantages are not realized unless the machine is suitably designed and its control circuit properly adjusted to supply the necessary voltages and currents. The purpose of this paper is to explain the design proportions and the adjustments of the supply voltages to provide for optimum operating characteristics.

THE characteristics of this adjustable-speed motor can be altered over a wide range by adjustment of either the magnitudes or phase relationships of the applied voltages, or by changes in the construction of the motor windings. While it may be desirable to make alterations to obtain certain characteristics, the more general problem is to make adjustments that will provide the best over-all characteristics for all speed settings. As an example, it is usually desirable to operate a motor with highest possible efficiency, but, with this machine, minimizing armature circuit resistance may ruin the speed-regulation characteristics. Thus the design proportions enter the problem from several angles, and criteria of design should not be based on one feature of the motor without regard to all consequences resulting therefrom.

In this particular system as in other adjustable-speed systems there are certain requisites that must be fulfilled to make the system practical. These requisites are as follows:

1. The design and adjustments of the machine should be such that it will operate satisfactorily for all speed settings.
2. The design and adjustments should be such that the best speed regulation is secured.
3. Throughout the load range of each speed setting currents should not be excessive. This is important in this machine because of the possibility of large no-load currents as well as large load currents.
4. The full load armature current should be approximately in phase with the armature voltage so that maximum capacity is obtained from the machine.
5. The efficiency should be high.
6. Commutation should be satisfactory.

Prevention of Overheating at No-Load

If the voltages supplied to the field and armature of this motor are adjusted to the proper phase difference at the highest-speed setting, no danger will result from the standpoint of armature heating at lower-speed settings. However, the reverse is not true. For if the phase of the field voltage relative to the armature voltage be adjusted for maximum power-factor correction at no-load for low-speed settings, the armature will overheat when the motor is operated at high speeds.

These phenomena can best be seen from Figure 1 which shows

(*a*). A circuit diagram used in supplying the motor.

(*b*). A vector diagram of the motor itself when adjusted for high-speed operation.

The dotted lines shown are for the same field adjustments (magnitude and direction of field voltage with respect to armature voltage), but with a lower-speed setting. When the motor armature is supplied with the voltage E_a, and the time phase of the field voltage is such that the flux ϕ crossing the air gap lags the armature voltage by α degrees, the generated voltage in the armature must have a locus along the line *ad*. The locus of this generated voltage must be parallel to the flux vector ϕ. The generated voltage must be of sufficient magnitude such that when it is added vectorially to the armature impedance voltage I_aZ_a the sum is equal and opposite to the applied voltage E_a shown as the distance *oa* for this high-speed setting. The voltage I_aZ_a due to the armature impedance is shown as the distance *op*.

When load is applied to the machine, the speed drops slightly. The generated voltage *ap* decreases slightly causing the impedance voltage drop *op* in the armature to shift clockwise with a corresponding shift in the resistance voltage drop of the armature shown here as the distance *oy*. Since the armature current *ox* is in time phase with the armature resistance voltage, an increase in motor load will likewise cause a shift of *ox* in a clockwise direction until the torque is sufficient to supply the load. This torque is equal to $K\phi ox \cos(\theta+\alpha)$ where K = the torque constant, *ox* is the armature current associated with the resistance voltage drop *oy*, and θ is the angle between the armature current *ox*, and the armature voltage *oa*. When load is removed, the process is reversed, and the impedance triangle *oyp* revolves counterclockwise until at no-load the I_aR_a vector *oy* and the I_a vector *ox* are perpendicular to the flux vector ϕ. For this condition the torque developed is zero. Thus for zero developed torque or true no-load on the motor, the armature current vector *ox* will always be perpendicular to the flux vector ϕ. When the voltage E_a supplied to the armature of the motor is reduced to a value *oa'* as shown in Figure 1*b*, the speed decreases, and the no-load current remains perpendicular to the flux vector ϕ. Since the angle α was not changed, the no-load value of the armature impedance voltage must be less. The new vector relations are defined by the dotted lines—that is, with an armature voltage *oa'* the generated voltage will be *a'q*, the armature impedance voltage *oq*, the armature resistance voltage *ow*, and the corresponding no-load armature current *oz*. Thus a reduction of speed caused by reducing armature voltage is associated with a reduction of no-load current, and vice versa. The phase of the field voltage with respect to the armature voltage must be adjusted so that the angle α between the flux vector and the armature voltage is sufficiently small to limit the no-load armature current for the high-speed setting to a value equal to or less than the rated current of the armature.

Adjustments for Minimum Speed Regulation

The preceding paper of this series showed that the speed of this motor decreases with increase in torque. Also, that the power factor becomes more lagging with increase in load. Change in speed with increase in load is usually undesirable in the adjustable-speed motor.

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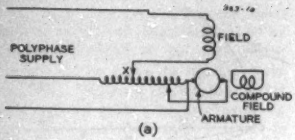
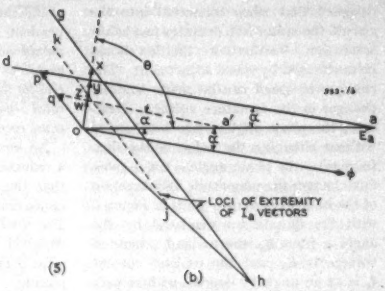


Figure 1

(a). The motor and supply circuit

(b). Vector diagram of the motor for two values of applied voltage



It is therefore desirable to make the speed regulation a minimum. Proportioning the armature circuit resistance and armature circuit reactance makes this possible. The proper proportions can be derived from the vector diagram of the motor shown in Figure 2.

The expression for the torque developed by this motor is

$$T = K\phi I_a \cos(\theta+\alpha) \tag{1}$$

where θ is the power-factor angle of the armature circuit considered, plus for leading power factors and minus for lagging power factors. K is a constant, and α is the angle between the flux vector ϕ and the voltage vector E_a.

By the law of sines

$$\frac{E_g}{\sin(\beta+\theta)} = \frac{I_a Z_a}{\sin\alpha}$$

Consequently

$$E_g = \frac{I_a Z_a \sin(\beta+\theta)}{\sin\alpha} \tag{2}$$

But

$$E_g = K'\phi N$$

where N is the speed of the motor and K' is a constant. Solving for N and substituting for E_g from equation 2, the speed

$$N = \frac{E_g}{K'\phi} = \frac{I_a Z_a \sin(\beta+\theta)}{K'\phi \sin\alpha} \tag{3}$$

Equations 1 and 3 provide expressions of torque and speed as functions of the variables θ and I_a. From the vector diagram and the law of sines

$$\frac{I_a}{\sin\alpha} = \frac{I_{ab}}{\sin(180°-\alpha-\beta-\theta)} = \frac{\frac{E_a}{Z_a}}{\sin(180°-\alpha-\beta-\theta)}$$

since

$$I_{ab} = \frac{E_a}{Z_a}$$

Therefore

$$I_a = \frac{E_a \sin\alpha}{Z_a \sin(180°-\alpha-\beta-\theta)} \tag{4}$$

Substituting equation 4 in equation 1, the expression for torque in terms of the one variable θ is obtained.

$$T = \frac{K\phi E_a \sin\alpha\cos(\alpha+\theta)}{Z_a \sin(180°-\alpha-\beta-\theta)}$$

Differentiating

$$\frac{dT}{d\theta} = \frac{-K\phi E_a \sin\alpha\cos\beta}{Z_a \sin^2(180°-\alpha-\beta-\theta)} \tag{5}$$

Substituting equation 4 in equation 3

$$N = \frac{E_a \sin(\beta+\theta)}{K'\phi \sin(180°-\alpha-\beta-\theta)}$$

Differentiating

$$\frac{dN}{d\theta} = \frac{E_a \sin\alpha}{K'\phi \sin^2(180°-\alpha-\beta-\theta)} \tag{6}$$

But

$$\frac{dN}{dT} = \frac{dN}{d\theta}\frac{d\theta}{dT} = \frac{E_a \sin\alpha}{K'\phi \sin^2(180°-\alpha-\beta-\theta)} \times \frac{-Z_a \sin^2(180°-\alpha-\beta-\theta)}{K\phi E_a \sin\alpha\cos\beta}$$

$$\frac{dN}{dT} = \frac{-Z_a}{K'K\phi^2\cos\beta} = \frac{-Z_a^2}{K'K\phi^2 R_a} \tag{7}$$

$$\frac{dN}{dT} = \frac{-R_a}{KK'\phi^2} - \frac{X_a^2}{KK'\phi^2 R_a}$$

From equation 7 it is evident that the slope of the speed-torque curve is a function of the flux ϕ and the impedance of the armature circuit Z_a. Both of these are essentially constant for all conditions of load. Therefore the slope of the speed-torque curve is a straight line. Experiments show this to be true. Further analysis of this equation reveals that to make the slope small (low-speed regulation) the flux ϕ should be large and the impedance of the armature circuit Z_a should be made as small as practicable. To determine the armature impedance angle β that will give a minimum slope to the speed-torque curve, equation 8 can be differentiated with respect to R_a. Let S equal the slope of this curve, then

$$\frac{dS}{dR_a} = \frac{-1}{KK'\phi^2} + \frac{X_a^2}{KK'\phi^2 R_a^2}$$

When

$$\frac{dS}{dR_a} = 0$$

$$R_a = X_a \tag{9}$$

and $\cos\beta$ which is equal to

$$\frac{R_a}{Z_a} = 0.707$$

or

$$\beta = 45°$$

Equation 7 shows that best speed regulation is obtained when the flux is large. Therefore the field circuit should be so

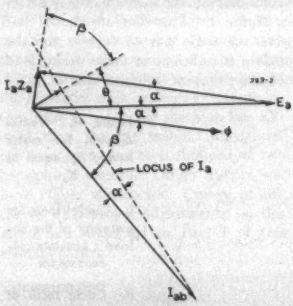
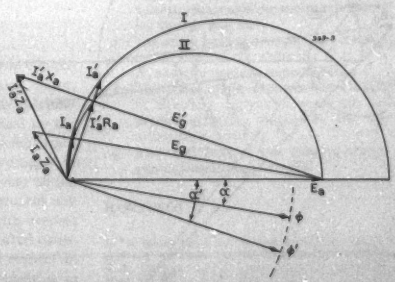


Figure 2 (above). Phase relations of currents and voltages in the vector diagram

Figure 3 (right). Vector representation of the effect of a change in the angle α

I. Circle locus of extremity of the no-load armature-current vector

II. Circle locus of extremity of the no-load I_aR_a voltage vector



designed that when connected into the circuit the stator iron operates just below saturation. Furthermore, this flux should be unchanged by speed adjustment. The changes in speed can be made best by changes in the armature voltage. However, the phase angle α can be changed without changing the value of the flux. Increasing the phase angle α for a given flux changes the magnitude and direction of the no-load current. Thus in Figure 3 with the flux vector displaced by the angle α from E_a, the no-load generated voltage is E_g, and the no-load current I_a is at an angle 90 degrees with respect to the flux vector. If the flux is held constant and the phase angle α shifted to the angle α', the generated voltage will be changed in magnitude and direction to the position of E_g'. This causes an increase in the armature impedance voltage from I_aZ_a to $I_a'Z_a$. The armature current is likewise increased from I_a to I_a', and the change in direction of this true no-load current corresponds to the change in direction of the flux vector. Since the no-load current vector is always perpendicular to the corresponding flux vector, it is also perpendicular to the corresponding generated voltage vector. Since the vector I_aR_a must be perpendicular to the vector E_g at no-load, the intersection of the vector I_aR_a with the vector E_g must be located on a semicircle the diameter of which is E_a. The extremity of the no-load armature current vector for different values of the angle α must also fall on a semicircle the diameter of which is coincident to the vector E_a, and of magnitude E_a/R_a units in length. Thus the magnitude of the no-load armature current for a given motor operated at its normal field strength will be dependent on the angle α. *This angle α should never be larger than that value required to make the no-load armature current for the highest-speed setting equal to the rated armature current. Larger angles will cause overheating at no-load.*

An analysis of equation 7 shows that a reduction of X_a to an ohmic value less than the ohmic value of R_a results in an improvement in the speed regulation. Therefore the armature circuit should be designed with the lowest leakage reactance practicable. This can be done by placing short-circuited compensating turns on the stator that are well coupled with the armature. These short-circuited turns should be well distributed, preferably in all slots. They should be made from copper straps or bars to save space and should be located as near to the armature conductors as possible. Having made the leakage reactance of the armature circuit as low as possible, the resistance of the armature circuit should be made equal to the ohmic value of the armature circuit leakage reactance. As shown in equation 9, this is necessary in order to obtain good speed regulation. If the leakage reactance of the armature circuit is greater than the resistance, the motor should have an external resistor connected in series with the armature in order to obtain the best speed regulation. The motor will then have a characteristic armature impedance such that the angle β is equal to 45 electrical degrees. The vector diagram for such a motor is shown in Figure 4. This diagram shows that when the angle β is 45 degrees and the angle α is sufficient to make the no-load armature current 100 per cent of rated value, the application of load causes the current to shift in direction until at full load the armature current op is directly in phase with the flux vector ϕ. Thus when the armature circuit resistance and reactance are made equal, the motor can correct power factor at no-load to the full extent of its rating, and under conditions of full load its current will be in phase with its flux giving maximum torque per unit of armature current.

Motors of this type can be designed so that the resistance and reactance of the armature circuit are approximately equal. If experiments indicate that the resistance is lower than the reactance, the addition of a small amount of resistance to the armature circuit may be desirable. For frequencies above 60 cycles, this may be necessary. If the motor is to be designed for frequencies less than 60 cycles, say 25 cycles, the reactance of the arma-

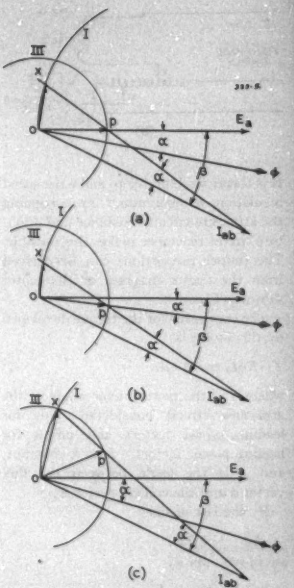


Figure 5. Vector diagram for armature circuit of the motor

(a). Angle α is 10 electrical degrees
(b). Angle α is 6 electrical degrees
(c). Angle α is approximately 16 electrical degrees

I. The locus of the extremity of the no-load armature-current vector

III. The locus of the extremity of the no-load I_aR_a voltage vector

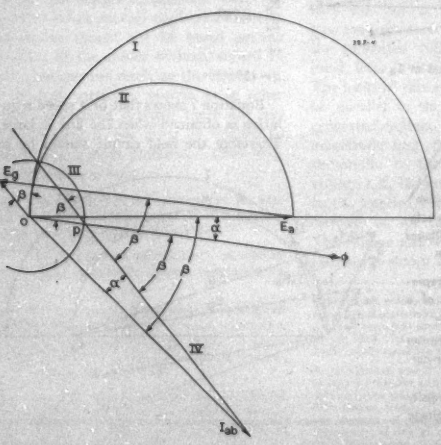


Figure 4. Vector diagram for motor having R_a equal to X_a

I. Circle locus of extremity of the no-load armature-current vector

II. Circle locus of extremity of the no-load I_aR_a voltage vector

III. Circle defining the 100 per cent value of armature current

IV. Locus of the extremity of the armature-current vector for different values of load

ture circuit may be less than the resistance. This is not objectionable, and by proper adjustment of the angle α the motor can be made to operate satisfactorily. Figure 5 shows the vector diagrams for such a motor having an armature impedance angle β equal to 25 degrees. Figure 5*a* shows that if the machine is adjusted to take a 100 per cent power-factor armature current at full load, it cannot correct power factor to the full extent of its rating as was possible when the angle β was 45 degrees. Figure 5*b* shows the diagram of the same motor as illustrated by Figure 5*a* except the angle α is made slightly less so that the armature will develop maximum torque with rated current. There is little difference in these adjustments since the power factor of the full load current is very nearly unity in both cases. More leading current at no-load with this same motor can be obtained by increasing the angle α as is shown in Figure 5*c*. The objections to this adjustment are evident from the diagram. The maximum available torque has been reduced, and consequently the horsepower rating of the machine with this adjustment is less. Thus if the armature circuit resistance is greater than its reactance, adjustment of the angle α should be such as to give conditions illustrated in Figure 5*a* or Figure 5*b*, but not those of Figure 5*c*.

Determination of Phase Angle of Armature and Field Voltage

The method of determining the proper phase angle between the armature and field voltage can best be explained on the basis of the vector diagram of Figure 5*a*. This method applies to any motor of this type having an armature circuit reactance equal to or less than its resistance. Armatures not so proportioned should have additional resistance connected in series with them to give such proportions. The steps in the procedure of making proper adjustments are as follows:

1. Determine the value of the standstill armature current I_{ab} for maximum armature voltage E_a. This can be obtained from low-voltage determinations of the armature impedance.

2. Draw the vector E_a as a reference for the maximum armature voltage to be applied to the motor and its corresponding standstill current I_{ab} at the proper angle β with respect to E_a.

3. Draw the circle locus I of the no-load armature current for different values of the angle α so that its diameter is coincident with the vector E_a and its length is E_a/R_a units in magnitude.

4. Using o as a center, draw the circle locus III of the 100 per cent value of the armature current.

5. Determine the locus of the extremity of the armature current vector by drawing a line through the extremity of the vector I_{ab} and the 100 per cent power-factor armature current op.

6. Extend the armature current locus to the no-load armature current circle. Determine intersection at X.

7. The proper value of the angle α between the flux vector ϕ and the armature voltage E_a can now be determined from the angle made between the lines representing the standstill armature current and armature current locus (the angle between I_{ab} and the line xp extended).

8. Apply maximum values of armature and field voltages to the motor such that the field voltage is approximately 90 degrees minus α ahead of the armature voltage.

9. With the motor running at no-load change the phase relation of the field and armature voltage by proper selection of tap x on the adjusting transformer until the armature current has a value corresponding to that of ox shown in Figure 5*a*.

This provides proper adjustment of the control circuit supplying the motor.

Efficiency

When the motor is adjusted as described in the preceding section, it will take a full load current at 100 per cent power factor. Such an adjustment will give optimum full load efficiency. Departures from these adjustments are apt to cause excessive currents because of low power factors, and damage to the machine may result from overheating. The full load copper losses of this machine are somewhat larger than those of a d-c motor of the same rating. The iron losses and the loss in the armature coils undergoing commutation tend to make the machine less efficient than the d-c motor. Efficiencies of 70 per cent have been obtained on two horsepower motors. Larger motors will have higher efficiencies. Curves of efficiency with proper adjustments on this motor are presented in Part I of this series of papers.[1]

Commutation

Commutation on this motor is comparable with that of the a-c series motor. The causes of brush sparks on this machine are essentially those caused by the inductance of the coils undergoing commutation and the induced voltages in those coils because of transformer action from the field. Since the brushes are located on a magnetic axis with respect to the stator field, they are located essentially in a neutral plane with respect to this field. Since the field is pulsating in nature and not rotating as in other polyphase a-c machines, it is much easier to obtain sparkless commutation on this motor, than on a motor which has its armature subjected to a rotating field flux.

There is a shift of flux in space with load on this motor because of armature reaction just as there is in a d-c motor. Consequently good commutation is obtained by shifting the brushes backward slightly with respect to the direction of rotation. This is satisfactory for small motors. Larger machines should be provided with interpoles.

The effect of the transformer voltages induced in the armature coils undergoing commutation can be made small in this motor by designing the armature for operation on low voltage. The control circuit makes this feature possible. By adapting a low-voltage armature to a high-voltage supply, by use of the autotransformer, and by shifting brushes slightly good commutation may be obtained.

List of Symbols

E_a—The voltage applied to the armature.
E_g—The effective value of the generated voltage in the armature.
I_a—The effective value of the armature current expressed in amperes.
I_{ab}—The effective value of armature current expressed in amperes when the motor is at standstill.
K—Torque constant of the motor.
K'—Generated voltage constant of the motor.
R_a—The equivalent resistance expressed in ohms of the armature and compensating winding.
S—Slope of speed-torque curve
T—The developed torque of the motor expressed in pound-feet.
x—The point on the adjustable transformer at which the field is connected.
X_a—The equivalent reactance of the armature and compensating winding expressed in ohms.
Z_a—The equivalent impedance of the armature and compensating winding expressed in ohms.
α—The phase angle expressed in electrical degrees between the applied armature voltage vector and the vector representing the air gap flux.
β—The angle having a cosine that is equal to the ratio of the armature resistance R_a to the armature impedance Z_a.
θ—The phase angle or power-factor angle in electrical degrees between the impressed armature voltage E_a and the armature current I_a.
ϕ—The total flux per pole crossing the air gap expressed in maxwells.

Reference

1. A New Type of Adjustable-Speed Drive for A-C Systems, A. G. Conrad, S. T. Smith, P. F. Ordung. AIEE Transactions, volume 62, 1943, January section, pages 7–10.

High-Voltage Power-Transformer Design

M. B. MALLETT
MEMBER AIEE

Synopsis: A core-type power-transformer design with shielded high-voltage winding and graded insulation has been developed for application in the higher-voltage classifications, and up to the present time more than one-quarter million kilovolt-ampere capacity of this kind of transformer has been manufactured and placed in service. The design employs a new form of construction for high-voltage power transformers which has been called "distributed concentric" construction. Outstanding characteristics of the distributed-concentric-type transformer include:

1. Reduced inherent reactance resulting in a reduction of critical materials for a given specification.
2. Ready adaptability to forced oil flow directed through the winding ducts resulting in a reduction of critical materials for a given thermal capacity.
3. Strategic distribution of voltage stress throughout the dielectric structure.
4. Simple and stable mechanical construction of windings, insulation, and shield.

POWER transformers for service in the higher-voltage transmission systems generally operate with grounded-neutral star-connected high-voltage windings, and the core-type transformer design described herein has been developed principally for this type of application.

In most core-type power transformers, as usually manufactured on this continent, the high-voltage winding of each core leg comprises the familiar stack of horizontal disc coils assembled over a conventional-type low-voltage winding. It is common practice to provide shielding and grade the insulation of these disc-coil stacks when designed for star connection and grounded neutral operation at the higher-voltage levels.[1] In general this shielding is secured by enveloping the high-voltage stack with a number of line potential shields which are so shaped and disposed as to supply each individual disc coil with its required charging current, as illustrated in Figure 1.[2] Grading of the major insulation in these transformers is ordinarily attained by special series-multiple connections of the high-voltage winding, in combination with variable diameter of individual disc coils, also illustrated in Figure 1.

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In the core-type design under consideration, termed "distributed concentric" design, the high-voltage winding of each core leg comprises a group of vertical helical coils which are concentrically distributed between a line potential cylindrical shield and the low-voltage winding, as illustrated in Figure 2. In general the high-voltage coils of each leg are series connected between line and neutral terminals and progressively spaced from the low-voltage winding and grounded end surfaces in relation to the individual coil potentials from ground. With this distributed arrangement of the high-voltage winding, adequate shielding is secured with a single cylindrical shield on each leg of the core, and the several coil-to-coil insulations not only serve individually as internal winding insulation but also function in series as graded major insulation to the low-voltage winding and ground.

I. Evolution of Design

From the viewpoint of shielding, the distributed concentric construction employs, in effect, a concentric series of relatively long and narrow "barrel" coils which are progressively disposed between the two plates of a condenser, an obvious general arrangement suggested in principle many years ago as a means of shielding.[3] As usual, however, the gap between principle and practical application is not readily bridged. In this regard, it is well known from service experience with ordinary single barrel applications in power transformers, that conventional-type barrel-coil structures without radial spacers tend to break down between turns under conditions of short circuit. Progressive arrangements of conventional-type barrel coils are commonly used in high-voltage testing-transformer design, but here there is no mechanical problem.

According to responsible engineers* recently escaped from Europe, the Allgemeine Elektricitäts-Gesellschaft have used power-transformer-winding arrangements in Germany within the past few years which comprise

1. A concentric series of barrel coils without radial coil spacers.
2. Each coil directly supported by a wound untreated paper cylinder with slit flanged ends and cooled by an outer axial duct.
3. The complete group of coils and untreated paper layers progressively wound with one set-up to form a virtually inseparable winding structure.

It is submitted, however, that such a construction is mechanically inadequate and unacceptable in respect to service conditions on this continent, since positive turn-to-turn separation is not provided, and neither secure factory clamping nor field replacement of individual coils is feasible.

The distributed concentric structure, as developed and specifically described, is offered as a new form of construction for high-voltage power transformers. In this construction positive axial separation of conductors is provided, and individual coils may be readily clamped and handled in the shop or replaced in the field as independent units—fundamental mechanical characteristics which have been standardized on this continent for many years by conventional disc-coil construction.

It will be shown that the distributed concentric transformer possesses highly desirable electrical and thermal characteristics, including low inherent reactance and ready adaptability to forced oil flow directed through the coil ducts, and the advantages of the general winding arrangement are by no means confined to the application of shielding.

II. General Description

Figure 3 illustrates some of the available high-voltage coil connections as applied to single-phase and three-phase designs. Ordinarily from four to six coils are used for each leg, corresponding approximately to a test level range from 277 kv to 576 kv respectively. In general top-to-bottom outside coil crossovers are cumbersome and to be avoided, particularly in the case of directed forced oil flow, and some of the connections shown are unique and have been devised to meet this condition.

Each high-voltage coil employs a new form of helical coil structure, as shown in Figure 4, in which a continuous wound-in spacer of channel section functions as the key feature. High-voltage taps are located in one or more coils of each leg and symmetrically spaced with respect to the coil center line, as illustrated in Figure 5, the tap straps being carried along the face of the coil in the axial cooling ducts and then outward through radial end ducts.

The low-voltage winding may be either

* Two members of the Association of Polish Engineers in Canada who are thoroughly familiar with recent transformer practice in Germany. The names of these engineers are withheld, since their families are still in Europe.

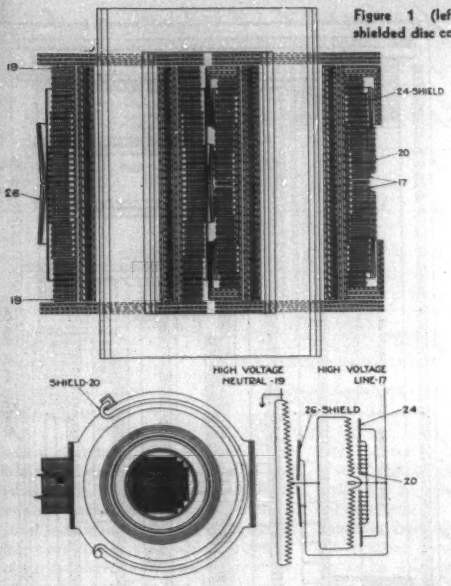


Figure 1 (left). General arrangement of shielded disc coil winding with graded insulation

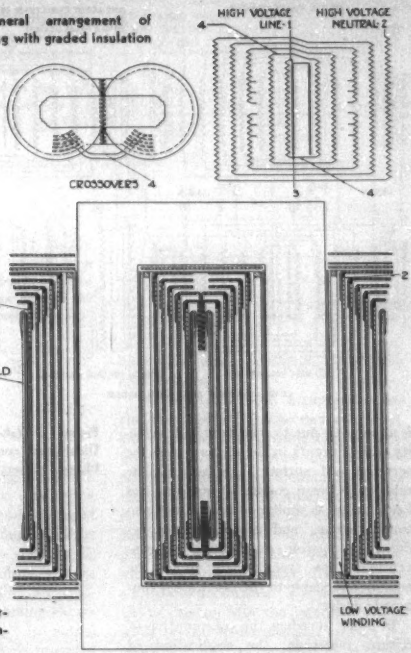


Figure 2 (right). General arrangement of distributed concentric design

of conventional type with horizontal ducts and intermittent spacers or of the same general type as the high-voltage winding. In the latter case, which is used in conjunction with directed forced oil flow, the number of coils will be substantially less than the number of high-voltage coils.

Insulation between adjacent high-voltage coils includes one winding cylinder and one axial oil duct in combination with independent flanged collars at the cylinder ends, as illustrated in Figure 4. The end insulation structure is designed around the coil-to-coil insulations, and the progressive radial end ducts are used for bringing out coil leads and tap straps.

The single shield of each core leg consists of a simple paper cylinder enveloping the outer coil and containing an embedded layer of circumferentially wound metal strip.

III. Inherent Reactance Characteristic and Associated Reduction in Critical Materials

The distributed concentric design has low inherent reactance resulting from the radial distribution of high-voltage ampere turns through the major insulation. This characteristic is illustrated in Figure 6, which compares the effective leakage width of two approximately equivalent hypothetical designs; one of the distributed concentric type and the other of conventional disc-coil construction. It will be seen that the reactance of the latter is approximately proportional to 5.5, a value more than 40 per cent greater than the corresponding figure of 3.9 for the distributed concentric design.

In this illustrative comparison, refinements in reactance calculation have been neglected for the sake of clarity, and the reactance ratio would vary somewhat from that shown, depending on the actual rating under consideration. It will be apparent to the transformer designer, however, that in general the distributed concentric construction employs a core some 20 per cent smaller in section than that required by conventional disc-coil construction for a given reactance and specification.

In addition to reducing the consumption of core steel by about one fifth, the decreased core dimensions result in a smaller volume of over-all physical structure with corresponding reductions in tank plate, clamp structure, oil, and insulation, and the total weight of critical materials is reduced by approximately one tenth. Thus, it is evident that the low inherent reactance characteristic of the distributed concentric design is of considerable practical significance, particularly under present wartime conditions when the necessity for conservation of critical materials is paramount.

IV. Thermal Characteristics and Associated Reduction in Critical Materials

The outer surface of each high-voltage coil is directly exposed to vertical oil ducts and heat flow from conductors is principally outward, although some loss is transmitted through the foundation cylinder. Thus, for any horizontal section taken through a coil, the temperature rise of each strand above local oil is readily determined by solution of an elementary series-multiple thermal circuit, once the thermal constants are established. The constants for solid insulation are well known, and a series of experimental direct-current heat runs indicated that the continuous spacer flanges, extending into the axial duct, only increase the oil-film constant of the vertical surface by about one degree for the usual design proportions. This surprisingly small effect of the spacer projections

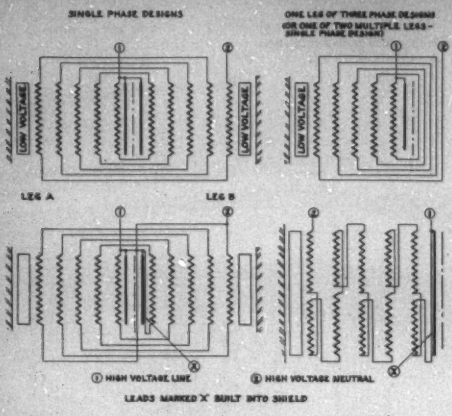

SINGLE PHASE DESIGNS
ONE LEG OF THREE PHASE DESIGNS OR ONE OF TWO MULTIPLE LEGS - SINGLE PHASE DESIGN
LOW VOLTAGE
LEG A
LEG B
① HIGH VOLTAGE LINE
② HIGH VOLTAGE NEUTRAL
LEADS MARKED 'X' BUILT INTO SHIELD

Figure 3 (above). Distributed concentric coil connections

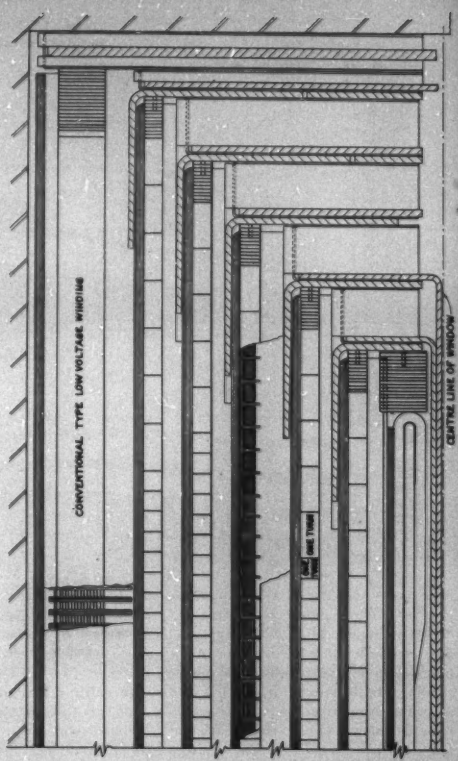


Figure 4 (right). Section through end portion of a typical structure

is apparently due to relatively high velocity eddy currents in the oil flow over the serrated coil surface. In general the relation between copper-oil gradient and load current is similar to that of conventional designs, and accepted rules defining permissible overloading of conventional-type transformers should be equally applicable to the distributed concentric design.

In order to reduce the consumption of critical materials, the application of external forced-flow heat exchangers to large transformers is rapidly increasing. With this type of cooling, a further reduction in materials results from directing the existing forced oil flow through the coil ducts, a condition readily attained in the distributed concentric construction merely by adding a simple pressboard barrier, as illustrated in Figure 7. It is evident from this drawing and Figure 4, that the inherent construction of the distributed concentric design is uniquely suited for directed-flow cooling, as contrasted with the unduly elaborate means obviously necessary in the case of conical-shaped stacks of horizontal disc coils.

The increased cooling effect of directed flow as compared to natural flow is illustrated by Figure 8, in which average and hottest copper rise above average oil are shown for both types of cooling. The curves are plotted for a typical coil, in which the increased insulation of the buffer wire is overcompensated by doubling the cooling surface per watt of the end turns, as shown in Figure 4, and the hottest strand is located in that turn of main wire which is adjacent to the upper buffer portion of the coil. Directed flow reduces the rise of the hottest strand above mean oil temperature in two ways, first by lowering the oil-film constant, and second by reducing the axial thermal gradient in the oil. The average copper rise above mean oil temperature is only affected by the first factor of reduced oil-film constant. For a given average oil temperature, the double-cause effect of directed flow on hottest copper rise is indicated by the considerable difference between curves B and B' of Figure 8, and the single-cause effect on average copper rise is indicated by the lesser difference between curves A and A'.

This substantial reduction in hot spot—average oil gradient resulting from directed flow—is important, since the actual thermal capacity of a transformer is determined by permissible hot-spot temperature. For example, a given transformer rated at 100 per cent continuous load with natural internal circulation and a given external cooler could be rerated by the addition of a simple pressboard barrier to approximately 120 per cent continuous load at the same hot-

Figure 5. Lowering a tap coil into the main assembly

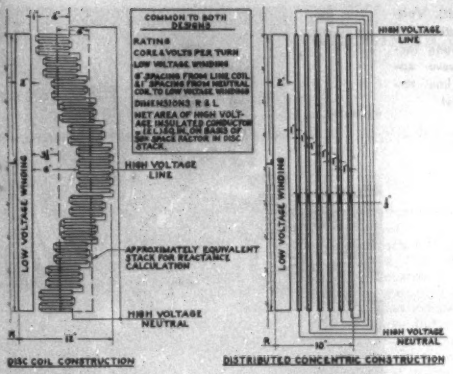

COMMON TO BOTH DESIGNS
RATING
CORE & VOLTS PER TURN
LOW VOLTAGE WINDING
6" SPACING FROM LINE COIL
6" SPACING FROM NEUTRAL COIL TO LOW VOLTAGE WINDING
DIMENSIONS R & L
NET AREA OF HIGH VOLTAGE INSULATED CONDUCTOR
(2.1 LBS. PER SQ. IN. ON BASIS OF 50% SPACE FACTOR IN DISC STACK.
HIGH VOLTAGE LINE
LOW VOLTAGE WINDING
APPROXIMATELY EQUIVALENT STACK FOR REACTANCE CALCULATION
HIGH VOLTAGE NEUTRAL
DISC COIL CONSTRUCTION
REACTANCE APPROXIMATELY PROPORTIONAL TO:
HIGH VOLTAGE LINE
LOW VOLTAGE WINDING
HIGH VOLTAGE NEUTRAL
DISTRIBUTED CONCENTRIC CONSTRUCTION
REACTANCE APPROXIMATELY PROPORTIONAL TO:

Figure 6 (left). Illustrative comparison of inherent reactance—distributed concentric versus disc coil construction

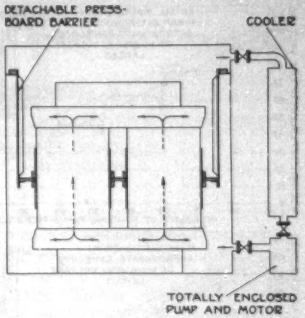


Figure 7 (right). Baffle arrangement for directing forced oil flow through the vertical coil ducts

spot temperature. Conversely, directed flow would result in a reduction of approximately 15 per cent in the total weight of critical materials required for a given continuous rating. Accordingly it is evident that the ready adaptability of the distributed concentric construction to directed forced oil flow may be conveniently utilized to substantially increase the kilovolt-amperes obtained per pound of critical materials consumed.

V. Distribution of Voltage Stress

Unless some form of shielding is provided, it is well known that the initial distribution of impulse voltage along a transformer winding departs radically from uniformity, and subsequent voltage oscillations ordinarily raise the potential of intermediate winding points to values which preclude any grading of the insulation. It is clear, however, that shielding to establish a perfectly uniform initial distribution, with absolute elimination of subsequent oscillations, is neither attainable nor necessary in practical design. The degree of shielding to be used in a transformer with graded insulation is therefore a question of economic balance and is determined by that combination of compromise shielding and partially graded insulation which has minimum over-all cost.

With a vertical front impulse applied to the line terminal, the initial or electrostatic voltage distribution along the winding of the distributed concentric transformer is fixed by the combined network of radial shunt capacities and axial series capacities, including the shunt capacities associated with the physical coil crossovers. The initial voltage distribution, corresponding to application of an infinitely long rectangular wave, is shown in Figure 9 for two alternative coil arrangements. Local oscillations of transition from initial to final straight line gradient overshoot the final gradient as an axis, and maximum voltage levels throughout the winding are indicated by the approximate ceiling shown as a straight broken line. In actual design, insulation strength is provided between parts of the winding and from winding to ground, corresponding to the maximum stresses thus created by application of an infinitely long rectangular wave. Since all real waves encountered in service must be of finite length and slope, the values of insulation strength as provided correspond to the upper

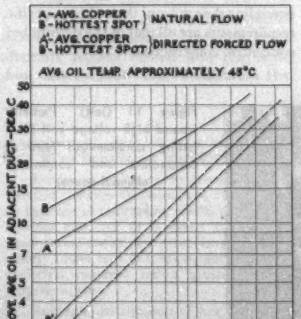

A - AVG. COPPER
B - HOTTEST SPOT
NATURAL FLOW
A' - AVG. COPPER
B' - HOTTEST SPOT
DIRECTED FORCED FLOW
AVG. OIL TEMP. APPROXIMATELY 45°C
RISE ABOVE AIR OIL IN ADJACENT DUCT - DEG. C
TOTAL COIL LOSS
NET OUTER SURFACE OF COIL
WATTS PER SQ. IN.

Figure 8. Effect of directed forced oil flow on copper—oil gradient

limit of stresses attainable for a given crest voltage.

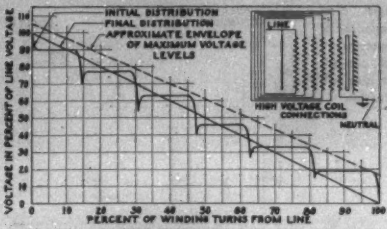
The re-entrant coil arrangement included in Figure 9 was devised principally to eliminate the objectionable outside vertical crossovers of the alternative straight-coil scheme. Examination of the respective voltage distributions, bearing in mind that the final impulse distribution also corresponds to the low-frequency gradient, will show that each arrangement requires approximately the same coil-to-coil allowances. The shunt capacities associated with the internal vertical leads of the re-entrant coil scheme are controlled by adjustment in physical width of lead conductors, and these capacities are conveniently utilized to substantially improve the initial voltage distribution as compared to that of the straight coil arrangement.

Because of the physical distribution of the high-voltage winding *through* the major insulation, it is evident that both low frequency and impulse voltage stresses, as shown in Figure 9, are advantageously distributed throughout the whole dielectric structure. Adequate control of impulse voltage on each leg of the core is readily secured with a single shield surface of plain cylindrical shape. Also greatly reduced and simplified shield insulation is sufficient, since the maximum voltage from shield to adjacent winding is ordinarily less than one third of line voltage, as compared to approximately full voltage in conventional construction.

VI. Mechanical Construction Including Shop Processing

The practicability of the distributed concentric transformer hinges on the mechanical characteristics of the physical structure, which in turn depend on specific details of construction, as illustrated in Figure 4 and explained below.

In each high-voltage coil the multiple



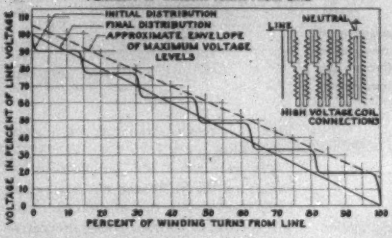


Figure 9 (left). Voltage distribution with infinitely long rectangular wave applied to line terminal

Figure 10 (right). Forming continuous channel spacer from flat pressboard strip

rectangular conductors are encased throughout their entire length by the continuous pressboard spacer of channel section, the conductors and spacer being simultaneously wound directly on a hard composition foundation cylinder. Ordinarily this spacer is $^1/_{32}$ inch thick, and the spacer flanges extend radially at least $^1/_4$ inch beyond the coil. Cross-grain pressboard end rings, in combination with the hard foundation cylinder, permit ready clamping and handling of each individual coil prior to assembly. Individual coils are progressively mounted in the main assembly as independent units, being finally supported and clamped to firm dimension by the end insulation structure which is progressively built around the independent flanged collars. The simple cylindrical shield structure is ordinarily wound on a hard foundation cylinder and also assembled in the main structure as an independent unit.

Under conditions of short circuit, the conductors of any cylindrical coil structure are subject to the formidable combination of pulsating axial force, pulsating circumferential stress, and elevated copper temperature with attendant thermal expansion. Thorough consideration of these factors and the unsatisfactory service record of conventional-type barrel coils lead to the conclusion that (1) positive axial separation of conductors, (2) firm coil clamping, and (3) freedom of coil-diameter expansion, are inescapable requirements for the prevention of conductor squirming and turn-to-turn breakdown. It is clear from Figure 4 and the preceding description that these specific requirements are all met in the distributed concentric construction.

It is further evident that all coils and parts may be disassembled and reassembled as separate independent units of the main structure. Thus, individual items, such as a high-voltage coil, could be furnished by the factory for field replacement and local damage repaired at the site without shipping the complete machine back to the shop. This feature is considered essential by most purchasers on this continent.

These fundamental mechanical characteristics, as specifically enumerated in respect to coil stability and field repair, have been standardized on this continent for many years by conventional disc-coil practice.

As further compared to conventional disc-coil construction however, the unique

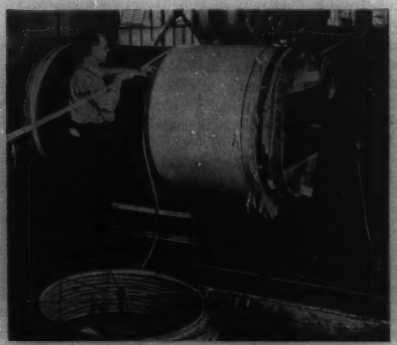


Figure 11 (left). Partially wound high-voltage coil illustrating simultaneous feed of conductors and continuous channel spacer

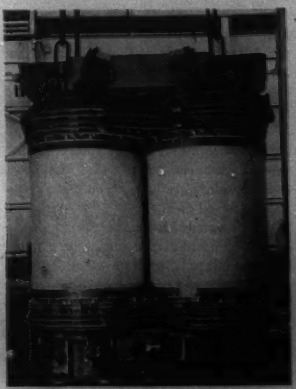


Figure 12 (right). Core and coils of single-phase 30,000-kva distributed concentric transformer, 323-kv test level

coil structure of Figure 4 comprises a solid cylindrical column of copper and insulation in which the shearing and cantilever actions of conical shaped disc-coil stacks are eliminated. Also the bearing surface between turns is continuous and uniform without the compression stress concentrations associated with intermittent radial spacers, and the entire cross section functions in the transmission of axial forces. It is further evident that the continuous-spacer feature eliminates the possibility of misaligned spacer columns, and the hazard of cutting the conductor insulation at the spacer edges. Intermittent radial spacers are used in the supporting-end insulation structure, but the continuous-bearing feature within the coil is maintained at the coil ends by the beam strength of the end ring and adjacent flanged collar combined.

Pre-forming of the continuous channel spacer from flat pressboard strip is illustrated in Figure 10. The automatic machine shown was designed especially for this purpose and normally produces channel spacer at the rate of one hundred feet per minute without an attendant. The advantages of this continuous spacer forming process from a production viewpoint are obvious, particularly when compared with the manufacture of a vast number of intermittent radial spacers which are individually sheared, punched, and assembled.

Figure 11 shows a partially wound high-voltage coil and indicates the manner in which the conductors and encasing channel spacer are simultaneously wound into the coil. It is evident that the winding process is substantially continuous, and the delays necessarily associated with intermittent spacers are eliminated.

Progressive assembly of the individual high-voltage coils as independent units is indicated by Figure 5, which shows a tap coil being lowered into a partially built structure.

VII. Summary

More than one-quarter million kilovolt-ampere capacity of the distributed concentric-type transformer has been manufactured and placed in service up to the present time. Figure 12 indicates the general external appearance of a typical core and coil assembly and illustrates the cylindrical shields, end-insulation structure, and horizontal coil crossovers.

Outstanding characteristics of the distributed-concentric-type design include:

1. Reduced inherent reactance, resulting in a reduction of approximately 10 per cent in total weight of critical materials required for a given transformer specification.

2. Ready adaptability to forced oil flow directed through the windings, resulting in an increase of approximately 20 per cent in thermal capacity of a given transformer and external cooler, or a reduction of approximately 15 per cent in total weight of critical materials required for a given kilovolt-ampere output.

3. Strategic distribution of low frequency and impulse voltage stresses throughout the whole dielectric structure, including a reduction of approximately 70 per cent in the voltage between shield and winding, the advantageous distribution of all voltage stresses resulting from the physical distribution of the high-voltage winding *through* the major insulation.

4. Simple and stable mechanical construction of high-voltage winding, insulation, and shield, including a new and improved form of helical coil structure and associated assembly which are mechanically suitable for application in large high-voltage power transformers.

References

1. Power Transformers With Concentric Windings, K. K. Paluev. AIEE Transactions, volume 55, 1936, June section, pages 649–59.

2. Figure 1 drawn from Canadian patent number 304,178. Inventor, K. K. Paluev.

3. Prevention of Transient Voltage in Windings, J. M. Weed. AIEE Transactions, volume 41, 1922, pages 149–55.

Experience With Oil Circuit Reclosers on REA Systems

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Synopsis: For three years surveys have been made of the operation of small single-pole automatic reclosing oil circuit breakers (also called "oil circuit reclosers" and "service restorers") on rural electric distribution systems financed by the Rural Electrification Administration. Results of these surveys indicate that the ratio of lockouts to operations is less than five per cent in most cases, and that there are from four to nine operations per month per breaker during the spring and summer, with each breaker controlling about 20 miles of line. The number of breaker failures and other breaker difficulties have been a small percentage of the total number of breakers installed. These surveys, together with discussions with system managers, have indicated that automatic reclosing breakers offer many advantages for rural line sectionalizing. Presently available breakers can be much improved in operating characteristics, and new sectionalizing devices are needed. This paper presents suggestions for such improvements.

THERE are now over 800 energized rural electric distribution systems financed by the Rural Electrification Administration, and these systems serve over 1,000,000 consumers. The average number of miles per system is about 470, and usually these lines radiate out of and are fed from a single supply substation. These rural lines extend out 40, 50, and sometimes over 60 line-miles from the power source. In general, the systems follow the radial design. In a few cases alternate feeders extend into the same area, but normally these feeders are not interconnected. The main feeders, two or more in number, consist of three-phase four-wire multigrounded neutral wye circuits with a nominal voltage of 7,200/12,450. Circuits, with two-phase wires and neutral, branch off from these feeders, and these "vee" circuits again split into single-phase circuits with one-phase wire and multigrounded neutral. Approximately 80 per cent of all distribution lines are single-phase 7,200 volts, and the greatest percentage of the consumer load is single phase. Outdoor unattended substations are used principally.

Individual systems will of course vary in detail from the average. Some are smaller and some larger. The larger systems usually divide the area into sections serviced by submaintenance centers. In the western mountainous regions the areas served are usually long and slender, and the lines follow the valleys. In these areas and in hilly regions, the

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The authors express appreciation to the REA cooperatives' operations division for assistance in securing information, to the system managers who furnished the data, and to the numerous REA engineers who gave assistance and suggestions, particularly M. W. Rothplets.

road distance to outlying sections may be much greater than the line distance.

Although progress has been made in improving rural roads, in many sections of the country road conditions leave much to be desired. During wet weather some of these rural roads become impassable.

Satisfactory telephone communication facilities generally exist in the more thickly populated farming areas, but in the more sparsely settled areas communication is sometimes poor and frequently practically nonexistent.

Table I. Report of Single-Pole Reclosing-Circuit-Breaker Operation on REA-Financed Systems in Iowa From Installation Until November 1, 1940

Number of systems reporting	20
Total number of circuit breakers reported	417
Number of design 1 breaker	163
Number of design 2 breaker	254
Total reported circuit-breaker months of operation	5,098
Total number of operations reported	20,973
Total number of lockouts reported where operations were reported	271
Per cent of lockouts to operations	1.29
Total operations where operations and number of breakers were both reported	20,973
Total number of breakers where operations and number of breakers were both reported	301
Average number of operations per month per breaker	4.11
Total reported breaker failures	59
Percentage of design 1 breaker failures per 12 months, where failures and months of operation were both reported	21.8
Percentage of design 2 breaker failures per 12 months where failures and months of operation were both reported	2.04

Most systems are equipped with open-gap-protected transformers.

All of the preceding information furnishes a picture to haunt the dreams of an operating man responsible for the continuity of service consistent with good operating practice. Rural service must be good. Farmers, using electricity for food-production purposes, need and are entitled to better service than urban resident consumers. In order to provide means for improving rural service continuity, the development of carrier-current communication, hot line work, routine testing, and so forth, for use on systems described, has been carried on. A heavy share of the responsibility for continuous service, however, must be borne by the sectionalizing devices. These must isolate trouble properly with a minimum of attention, and REA has been very interested in adequate sectionalizing apparatus and methods.

In the early stages of the REA program, most systems were designed to be sectionalized with fuses. Three-shot repeating cut-outs were installed on main feeders, and single-shot cut-outs served on branch lines. Few substations were equipped with oil circuit breakers; three-shot cut-outs served at these locations. Since then, the fused system has been used very extensively, but, since experience has shown that many unnecessary outages occurred with the single-shot cut-out, the trend has been toward using fewer single-shot cut-outs and using more of the repeating type.

In 1936, 7,500-volt automatic reclosing and recycling single-pole circuit breakers were available, which were recommended for use on circuits up to 7,500 volts. These were installed on single-phase lines on a number of rural systems in conjunction with open-gap-protected distribution transformers. One object of these installations was to reduce construction costs by eliminating lightning arresters, and another object was to determine if such a device would be advantageous in decreasing service interruptions. In particular, many Iowa systems and some Ohio systems used this construction.

Experience with the 7,500-volt breaker installations proved that a device which would automatically recycle to original position after a temporary fault and would reclose two or three times, then lock out on a permanent fault, would do much to reduce system outages. However, because of the low insulation level of the device, a considerable number of breaker failures were experienced, most of these from lightning surges (see Table I). Because of these difficulties, use of this device was largely abandoned.

About 1939, stimulated by REA engineers and others, a 15-kv single-pole self-contained automatic reclosing oil circuit breaker was developed. The breaker opening time was very short (usually less than 0.1 second), and the time between all three reclosures was about three seconds and was unadjustable. Systems along the eastern seaboard decided to try out this device. In about a year's time 1,000 such circuit breakers had been installed. Each of these systems was separately studied for proper application of these devices.[2] Following a thorough study, taking into consideration the proper application of these breakers from the viewpoint of safety, accessibility,

Table II. Report of Single-Pole Reclosing-Circuit-Breaker Operation on REA-Financed Systems, May to November 1941

Month	Number of States Represented	Number of Systems Reporting	Number of Breakers Reported	Average Miles of Line Per Breaker	Operations Per Breaker	Operations Per Mile	Per Cent Lockouts to Operations
Systems With Arrester-Protected Transformers							
May	7	10	69	31.3	6.01	0.192	1.88
June	10	17	192	24.2	9.07	0.375	2.53
July	15	28	323	27.8	9.69	0.349	1.73
August	15	35	405	31.9	7.93	0.249	2.71
September	18	36	368	32.2	2.55	0.079	3.63
October	13	18	189	30.7	2.69	0.088	13.4*
Systems With Open-Gap-Protected Transformers							
May	7	23	428	18.4	4.24	0.230	2.70
June	10	31	580	18.0	5.97	0.332	2.31
July	11	41	662	18.9	7.60	0.402	1.73
August	13	46	684	19.7	6.70	0.340	1.55
September	15	47	697	19.5	6.50	0.333	2.50
October	12	30	336	18.6	5.37	0.289	5.09

* Due to a large number of trees breaking on one system.

Table III. Report of Single-Pole Reclosing-Circuit-Breaker Operation on REA-Financed Systems Which Reported the Same Number of Breakers for the Three Consecutive Months of July, August, and September 1941

	All Systems	Systems With Gap-Protected Transformers	Systems With Arrester-Protected Transformers
Number of states represented	17	9	14
Number of systems reporting	35	18	21
Number of breakers reported	450	204	246
Miles of line controlled	11,441	4,150	7,291
Average miles of line per breaker	25.4	20.4	29.6
Number of breaker operations	8,094	3,228	4,866
Total operations per breaker	18.0	15.8	19.8
Total operations per month per breaker	6.0	5.3	6.6
Total operations per mile	0.706	0.778	0.668
Total operations per month per mile	0.235	0.259	0.223
Number of breaker lockouts	208	77	131
Lockouts per month per breaker	0.154	0.126	0.177
Lockouts per month per mile	0.00607	0.0062	0.00598
Per cent lockouts of operations	2.57	2.38	2.69
Operations per lockout	38.9	41.9	37.1

co-ordination, and cost, a definite program was recommended for breaker installations so as to attain the maximum benefit from their use. This study indicated that the breaker investment would pay greater dividends when the device was located at the more remote sectionalizing points, and hence the first breakers were installed at a distance from the power source, and as additional breakers were obtained, installations were made progressively nearer to the power source. No discrimination was made as to the type of transformer protection. Existing cut-outs were left in place at sectionalizing points on the load side of the breakers and used as disconnects. Experience with these circuit breakers has been so favorable that since then many additional systems have installed such devices and REA-financed systems now have over 5,500 such single-pole automatic circuit breakers.

The first detailed survey of circuit-breaker performance was made in 1940, when the Iowa systems were asked to give their experience from the date of installation to November 1, 1940. Unfortunately, most of the systems kept no adequate records of some phases of such breaker operation, and the investigation was made more difficult by the fact that the counters of the older 7,500-volt breakers were internally placed. However, out of the replies furnished, the most adequate data were assembled as shown in Table I. It is remarkable how closely such data check with the more accurate information obtained during the next two years.

Most of the failures on the design 1 breaker were due to lightning damage to the pocket-type bushing and insulated lead. The next greatest failure cause was overload, which in turn was due to incorrect application. The design 2 breakers showed a very much lower failure rate.

In order to obtain more detailed and accurate data and to cover more cases, during the 1941 lightning season all REA-financed systems with circuit breakers were asked to make breaker counter readings each month and to report the number of lockouts and the cause of each. Tables II through V give the results of this survey. (The term "Gap" means an open air gap of definite dimensions which has no means of extinguishing the flow of power follow current.)

Systems which reported the same number of breakers for the three consecutive months of July, August, and September were segregated, and Table III gives the breakdown or analysis of data for these systems.

Table IV shows the cause of all the reported lockouts, irrespective of month or system, and Table V shows the breaker difficulties experienced.

Since any failures or other difficulties with breakers were reported separately, and since systems which did not furnish operation and lockout data often did report such difficulties, the tabulation in Table V represents many more breaker installations than reported in the other tables and covers the entire year. Hence, the percentage of failures to installations could not be determined, although apparently it is very low.

During 1942, because of the gasoline and tire shortage, REA-financed systems were asked to make complete counter readings only on April 1 and on October 1 but to make lockout reports each month. In 1941 two additional manufacturers had breakers available, and some systems with these makes were included in this survey. These new makes have different characteristics and construction from the older makes, but in general the operation is the same. Table VI gives a summary of the data collected in the 1942 survey.

In the 1942 survey, lockouts were reported each month, and, if no report was obtained after a letter follow-up, it was assumed that no lockouts occurred. Hence, some lockouts may have been omitted, accounting for the lower percentage of lockouts to operations than in 1941.

Figure 1. Estimates of average cost to re-fuse one cutout by 132 REA-financed systems with 1,337 breakers. January 1 to October 1, 1942

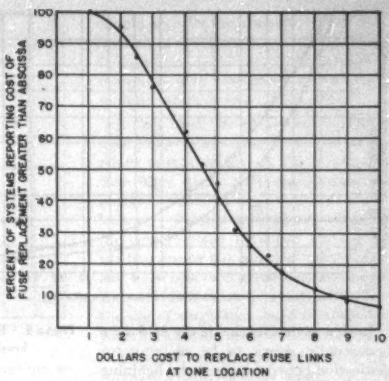

Table IV. Report of Single-Pole Reclosing-Circuit-Breaker Operations on REA-Financed Systems, May to November 1941

Cause of Breaker Lockouts

Number of states reporting	20
Number of systems reporting	72
Total lockouts reported	773
Percentage lockouts due to:	
1. Conductor break	7.3
2. Pole break	3.1
3. Insulator failure	7.5
4. Arrester failure	4.5
5. Transformer failure	9.8
6. Trees	30.7
7. Other	21.1
8. Not known	16.0

Table V. Report of Single-Pole Reclosing-Circuit-Breaker Operation on REA-Financed Systems

Reported Difficulties Experienced With Breakers—1941

State	Number of Breakers Affected	Description of Difficulties	Probable Cause of Difficulties
Florida	5	Oil gauges did not work	Fiber gauge rod injured in shipment
	1	Breaker jacket injured	Lightning
Georgia	2	Did not reclose	Rust on trip counters
Iowa	2	Gears stripped on recycling device	Breakers improperly located on system
	1	Coil lightning protector failed	Lightning
	1	Failure to operate	Not known
Minnesota	4	Failure to operate	Lightning*
North Carolina	1	"Burned out"	Not known
South Carolina	2	Registers did not operate	Not known
Texas	1	Coil protector failed—breaker case shattered	Lightning
Wisconsin	1	Breaker case shattered	Not known
Total	21		

* These are an older model.

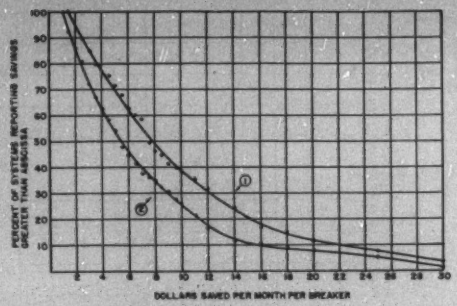

Figure 2. Estimates of monetary savings using breakers over previous practice

Curve 2 shows estimates of savings in operation and maintenance costs by 100 REA-financed systems with 1,078 breakers. Curve 1 shows estimates in savings in operation and maintenance plus savings in retail sales by 53 REA-financed systems with 507 breakers. January 1 to October 1, 1942

In view of the fact that in the field there occasionally seems to be no clear-cut distinction between a gap and a lightning arrester, a few errors may exist in the 1941 and the 1942 surveys in separating the systems with gap-protected transformers and the systems with arrester-protected transformers. However, errors from this cause are small and should have little effect in the over-all results as shown on the summary for the period covered. The surveys indicate that there were about 26 per cent more operations of the breaker per mile of line with gaps than with arresters in 1942 and about 16 per cent more in 1941. Lightning protection is provided only at each distribution transformer, or on about 20 per cent of the poles on rural circuits. Each unprotected pole provides a potential point of flashover, and each such flashover will probably cause an operation of the breaker. Since the arrester will usually stop follow current without breaker operation, while the gap will not, the additional operations per mile with gap-protected transformers can be expected.

Table VII shows the reported cause of all reported 1942 lockouts. Table VIII gives a summary of the breaker difficulties experienced. As in 1941, Table VIII represents more breaker installations than reported in the other tables, and covers the entire year.

Records for circuit-breaker operation have not been obtained for winter months. Experience has shown that during this period the number of operations reduces considerably. Numerous letters and reports from system managers indicate that the oil circuit breaker is very effective in preventing outages caused by unequal snow loading and tree limb contacts. Particular attention is called to the fact that these systems have been operating with reduced personnel under national defense and wartime conditions. Because of this situation an interesting aspect of the use of the circuit breaker which showed up on some systems was that tree trimming and right-of-way clearing were often deferred if other work was pressing, allowing the breakers to take care of the situation.

In the 1942 survey an attempt was also made to ascertain the monetary savings experienced by REA-financed systems using breakers. Systems were asked to furnish estimates on such savings. Figures 1 through 3 give the results of this survey. Figure 1 shows a percentage distribution of estimated savings for replacing fuses in a cut-out at one location. Experience has shown that circuit breakers usually show a greatly higher operation rate than the previous rate of fuse blowings at the same location. This may be caused by breaker operations occurring during the time which was formerly taken to replace the blown fuses. It is therefore not proper to multiply the number of breaker operations by the cost to replace fuses at a given location in order to obtain the total savings. Hence, the systems were asked to give estimates on the monthly savings effected by breakers, and these are shown in Figure 2. Figure 3 shows the estimated breaker maintenance and replacement cost. These three charts are for the period of January 1 to October 1, 1942. Maintenance costs on the breakers, now low, will probably increase as the units become older.

Correspondence and discussions with various REA system managers indicate that the continuity of service brought about by the breakers is of far more importance than the savings in maintenance and operations expenses afforded by them. It is difficult to get at any

Table VI. Summary of Survey of Single-Pole Reclosing-Circuit-Breaker Operation on REA-Financed Systems, April 1 to October 1, 1942

	All Systems	Systems With Gap-Protected Transformers	Systems With Arrester-Protected Transformers
Number of states represented	31	23	29
Number of systems reporting	162	88	99
Number of breakers reported	2,455	1,314	1,141
Miles of line controlled	55,238	26,680	28,558
Average miles of line per breaker	22.6	20.3	25.0
Number of breaker operations	98,858	53,714	45,144
Total operations per breaker	40.3	40.8	39.5
Total operations per month per breaker	6.7	6.8	6.6
Total operations per mile	1.79	2.01	1.58
Total operations per month per mile	0.298	0.335	0.264
Number of breaker lockouts	1,840	877	963
Lockouts per month per breaker	0.125	0.111	0.141
Lockouts per month per mile	0.00555	0.00548	0.00562
Per cent lockouts of operations	1.87	1.63	2.14
Operations per lockout	53.7	61.2	46.8
Per cent consumer hours outage time	0.105	0.097	0.111

Table VII. Report on Operation of Reclosing Oil Circuit Breakers on REA-Financed Systems April 1 to October 1, 1942

Cause of Lockouts

Number of states reporting	31
Number of systems reporting	163
Total lockouts reported	1,930
Percentage of lockouts due to:	
1. Conductor break	10.1
2. Pole break	1.9
3. Insulator failure	11.8
4. Arrester failure	5.4
5. Transformer failure	5.6
6. Trees	25.5
7. Other	18.5
8. Not known	21.2

Table VIII. Report on Survey of Single-Pole Reclosing Circuit Breakers on REA-Financed Systems, 1942

Summary of Reported Difficulties

Probable Cause of Difficulties	Number of Breakers
Lightning	13
Defective or broken ratchet mechanism	7
Warped or defective lockout mechanism	8
Overload	3
Burned contacts or worn parts	4
Dirty	3
Excessive or insufficient fault current	4
Noninterruption of fault	1
Other	3
Not known	10
Total	56

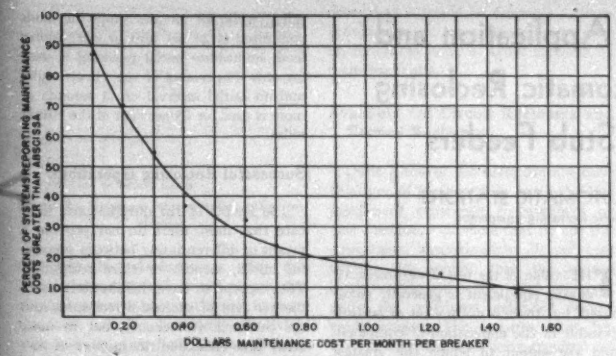

Figure 3. Estimates of breaker maintenance costs by 47 REA-financed systems with 624 breakers, January 1 to October 1, 1942

figures on the number of consumer-hours outage time saved by the breaker system over the fused system, as few of the fused systems kept any detailed records of outage time. Indications are, however, that the improvement in most cases is substantial.

These surveys and other experience have indicated that the automatic reclosing oil circuit breaker offers great possibilities for rural electric system sectionalizing. Since most of the REA lines are single phase, the greatest requirement is for single-pole breakers. Some systems, particularly those serving a large amount of irrigation load, use automatic reclosing three-pole breakers. In order to prevent voltage from appearing on an opened phase through ungrounded wye transformer banks and also to prevent single-phase power being applied to three-phase motors, it appears that three-pole breakers on feeders may become more necessary as the many small industries continue to spring up around established REA systems requiring more and more three-phase power.

The circuit breaker will probably not entirely replace the fused cut-out immediately or even in the future. In some locations, where the routine patrolling is of sufficient frequency, the fused cut-out may be more economical and the service maintained as satisfactorily as with the automatic breaker. Also, if a breaker such as described hereinafter can be obtained, single-shot fuse cut-outs can be used on short branch lines beyond such breakers.

One of the major questions in the future development of the small distribution-type circuit breaker is the question of time delay in opening. From the standpoint of protection to equipment and prevention of conductor failures caused by arc-overs, the breaker should open as rapidly as possible. On the other hand, one of the objections to the fast-opening breaker has been that occasionally a damaged distribution transformer takes a line section out of service because the breaker locks out prior to the blowing of the primary transformer fuse. Lockouts from this cause seldom occur, but, when they do, a large number of consumers may experience a long outage. Also, it is believed that time delay should afford an opportunity to co-ordinate a greater number of breakers in series and should provide better operation when picking up motor loads.

Limitations are often imposed by the power supply agency, which usually specifies the supply side fuse size on the substation. If the purpose of this limitation is to insure co-ordination with relays further back on the transmission system, it can be understood, but unfortunately in many cases the supply side fuse size seems to be specified on no particular technical basis. Proper sectionalizing depends on system fault currents and time-current characteristics of apparatus, and the supply side fuse or other device is intended to operate only for short circuit in the substation or in case the load side device fails. As pointed out by Marsh and Dodds,[3] it is not always possible to expect complete co-ordination of the substation fuse with transmission-line relays over the entire range of fault currents and still allow adequate sectionalizing by the consumer. In particular instances, discussion of the problem with supply agencies has usually resulted in a revision of requirements, and it is hoped that eventually all supply agencies will co-operate with consumers in reaching a solution satisfactory to both parties.

In any case, the protection of equipment and the increasing use of high-speed relays puts a ceiling on the amount of time delay used, particularly since the breaker reopens three or four times for a lockout. Present indications are that the device should have fast opening on the first one or two openings and moderate time delay on succeeding openings. This would effect a compromise and allow the use of single-shot fused cut-outs beyond the breakers on short branch lines.

A possible specification for a small distribution circuit breaker would have it satisfy the following requirements:

(*a*). The breaker be rugged and dependable.

(*b*). Be self-contained, requiring no current or voltage transformers.

(*c*). Be entirely automatic.

(*d*). Be equipped with two instantaneous openings and two subsequent time-delay openings to lockout, with recycling to original position for a temporary fault.

(*e*). Contain lightning and overload protection.

(*f*). Have a high insulation level.

(*g*). Have a fairly simple mechanism, easy to repair.

(*h*). Be inexpensive.

Future developments in rural electrification point to increased use of three-phase lines and interconnection of lines into networks. This trend will call for some sort of directional control on breakers. Devices which will distinguish between load and fault currents of the same magnitude are required. There is much to be done in the rural electric distribution field, particularly in circuit control.

References

1. Interim Report on Application and Operation of Automatic Reclosing Equipment on Stub Feeders, AIEE subcommittee on a-c automatic reclosing equipment. AIEE Transactions, volume 62, 1943, August section, pages 536–40.

2. Procedure for Making a Sectionalizing Study on Rural Electric Systems. *Technical Standards Bulletin* 4, United States Department of Agriculture, Rural Electrification Administration.

3. High-Voltage Fusing of Transformer Banks, H. H. Marsh, Jr., G. B. Dodds. AIEE Transactions, volume 61, 1942, July section, pages 533–5.

Interim Report on Application and Operation of Automatic Reclosing Equipment on Stub Feeders

AIEE COMMITTEE ON AUTOMATIC STATIONS
Subcommittee on A-C Automatic Reclosing Equipment

Preface: The present war emergency requires that the maximum use be made of existing equipment and systems and that a minimum of critical material be used for new equipment.

This publication and other guides and reports in this series have been prepared for the information of users during the war emergency. Upon termination of the war emergency they will be reconsidered by the Standards committee and the committees which prepared them, and will be approved, revised for normal use, or rescinded.

This procedure is being followed in preference to the preparation of special emergency standards which might involve redesigning and drastic changes in manufacturing practices. These guides will accomplish the maximum conservation of critical materials, since they provide for the maximum use of existing equipment and systems, as well as new equipment without changing the fundamental basis on which the present standards have been prepared.

Synopsis: This report presents the results of a survey which has been made to obtain data on typical present-day a-c automatic reclosing equipment and practices as applied to stub feeders having a single end source of power. The data received provide a good summary of the reclosing practices in general use and the performance being obtained. It also gives an indication of the possibilities of using immediate initial reclosure more extensively for some types of loads. This subject is of timely interest because of the possibilities of conserving critical materials in such cases where the application of automatic reclosing equipment will defer the necessity of providing additional circuit facilities.

Paper 43-84, recommended by the AIEE committee on automatic stations for presentation at the AIEE national technical meeting, Cleveland, Ohio, June 21–25, 1943. Manuscript submitted April 7, 1943; made available for printing May 10, 1943.

Personnel of the subcommittee on a-c automatic reclosing equipment: J. A. Rizi, *chairman;* J. T. Logan, G. S. Whitlow.

This report was prepared by the AIEE subcommittee on a-c automatic reclosing equipment of the committee on automatic stations for the purpose of making essential information immediately available to war industries, thus furthering the conservation of valuable material for the war emergency. It is educational and in no way mandatory. It is not intended as a "Standard" and has not been approved formally by the Standards committee or the board of directors.

It will be noted in the tabulation that 41 users furnished the data summarized in this report. The committee on automatic stations expresses its sincere appreciation to these organizations for their co-operation.

THE value of the use of automatic reclosing equipment is generally recognized, but there is quite a bit of latitude possible in the application of equipment and the extent to which the greatest benefit will be derived from it. Operating experience plays an important part in determining the most suitable type of equipment and the optimum settings.

The scope of this survey was limited to stub feeders which are energized from one source only and which do not require voltage-checking devices nor synchronizing relays.

The data presented in this report are based on information supplied by 41 users and represent a total of over 100 typical applications covering a little more than 70,000 miles of circuits in use by various companies or governmental units in the United States and Canada. The operating voltages range from 2,300 volts and above, and the data submitted cover both isolated and grounded neutral systems. A summary of the data regarding types of equipment used, reclosing cycles, and performance is given in Table I.

Reclosing Cycle

In analyzing the data regarding the reclosing cycle most commonly used, it was felt that it would be most significant to study the information on the basis of the interval of time used for the first reclosure and to apply a weighting factor proportional to the circuit miles for which any particular initial reclosing cycle is used. The time interval used for the second and third reclosures varies rather widely and depends on such factors as allowable breaker duty, relaying requirements, and allowance for clearing of temporary faults caused by tree limbs and swinging conductors. An analysis of the data received made on the aforementioned basis is shown in Figure 1. Immediate initial reclosing was reported for 70 per cent of the circuit miles for all types of loads. For circuits supplying 75 per cent or more residential load, immediate initial reclosing is used for 88 per cent of the circuit miles, while for circuits supplying loads comprised of 25 per cent or more motor load, immediate initial reclosing is used for only 30 per cent of the circuit miles and an initial interval of 15 seconds or more is used for 68 per cent of the circuit miles.

Successful Reclosing Operations

The results of the questionnaire indicate that most users do not provide a means of differentiating between successful initial, second, or third reclosures. They appear to have definite data as to the per cent of successful reclosures and the per cent of lockouts, but in most cases have estimated the number of successful reclosures which were second and third intervals. Figure 2 has been prepared to show the successful initial reclosing performance in terms of circuit miles, and Figure 3 gives the average for all companies weighted in proportion to the circuit miles. From Figure 2 it will be seen that 80 to 90 per cent successful initial reclosing performance was reported for 53 per cent of the circuit miles and 70 to 80 per cent successful reclosure for 34 per cent of the circuit miles. Figure 3 indicates that service is restored on the initial reclosure for 76 per cent of the circuit miles.

Change of Relaying Time After Initial Reclosure

For about 75 per cent of the types of circuits reported, no provision is made for

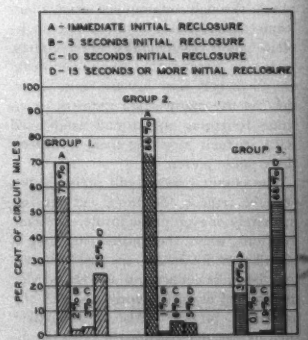

Figure 1. Summary of initial reclosing intervals

Group 1. Average for all types of loads

Group 2. Average for circuits having 75 per cent or more residential load

Group 3. Average for circuits having 25 per cent or more motor load

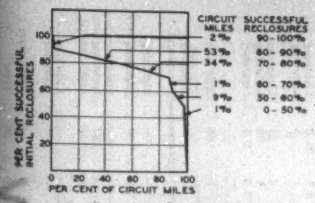

Figure 2. Summary of successful initial reclosures

changing the relaying time after the initial reclosure which would permit the circuit breaker or service restorer to clear the fault initially, providing selectivity with fuses or other fault clearing devices for subsequent reclosures. Of the 25 per cent of the users who do use this type of relaying, several have kept quite complete records and appear to be obtaining satisfactory results. Various schemes of providing this type of relaying were described. Some companies make use of a contact on the reclosing relay, others provide separate plunger-type relays, and in some cases this feature is incorporated in the service restorer.

Available Reclosing Relays

A large majority of the users reported that the present available reclosing relays are satisfactory for their systems. There was an expression on the part of some users that it would be desirable to have provision made for a quicker reset time on reclosures so as to avoid lockouts on recurring faults.

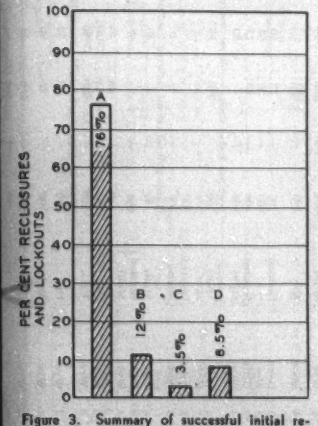

Figure 3. Summary of successful initial reclosures

A. Successful initial reclosures (including immediate and time delay)
B. Successful second reclosures
C. Successful third reclosures
D. Lockouts

Available Oil Circuit Reclosers and Service Restorers

Quite a few of the users did not have this type of equipment in service or had insufficient experience to comment on this question. Of those that do use this equipment, approximately 50 per cent express the opinion that the present equipment is satisfactory and adequate, while the remainder indicated desired modifications. The features most frequently mentioned as being required are as follows:

(*a*). Greater interrupting capacity.

(*b*). Better time-delay features to permit co-ordination with fuses and other fault-clearing devices.

(*c*). Higher continuous current ratings.

Most of the users indicated a decided preference for three-pole devices when used on three-phase circuits and single-pole devices on single-phase circuits.

Repeater Fuses

Some 90 per cent of the operators using repeater fuses do not seem to find that the lack of the self-resetting feature results in excessive lockouts. Most of the users report that customary patrols of circuits are adequate to prevent excessive lockouts from this cause and do not indicate an excessive amount of patrolling being required to obtain this performance.

Maximum Time of Circuit Interruption Without Dropping Motor Load

Only a relatively few users have factual data regarding the maximum time a distribution circuit can be de-energized without dropping an appreciable part of motor load. However, those who did present data appear to have analyzed the situation rather carefully, and it is felt that the information given is therefore quite significant. Figures of 0.5 to 2 seconds appear the most frequently. One user reports the results of tests which indicate that for 98 per cent of the motors tested, an interruption of from 1 to 2.2 seconds would not result in dropping the induction motor load.

There is quite a divergence of practice in the application of immediate reclosure for motor loads. Some users have adopted the practice of providing no immediate reclosure for any motor loads, but many report satisfactory performance with immediate reclosure for induction motors, and a few use this type of reclosure for synchronous motors as well. In this connection there are several considerations mentioned which are worthy of note:

(*a*). For the successful application of immediate reclosure for motor loads, special consideration may need to be given to the type of load served and the product being manufactured.

(*b*). Time delay is provided for undervoltage release devices where used.

(*c*). For some synchronous motor loads it may be necessary to provide suitable equipment such as field removal relays, unloading devices, and so forth, to insure satisfactory operation.

The replies to this part of the questionnaire indicate that there is a need for special study in applying reclosing equipment to some motor loads, especially synchronous motors and that there is a definite possibility of utilizing the benefits of immediate reclosure on motor circuits to a much wider extent than is now being done.

Minimum Permissible Reclosing Cycles

Here again it was found that there is a dearth of factual data regarding the minimum time required between reclosures to assure deionization of the arc path. Many of the users reporting on this part of the questionnaire expressed the opinion that an interval of approximately 0.5 second is satisfactory, while it was pointed out also by several that the time interval obtained by the use of normal speed breakers and immediate reclosing relays has resulted in no trouble because of restriking of the arc. Some do, however, feel that a period of 3 to 5 seconds should be allowed to permit swinging conductors to separate and falling tree branches to clear from the lines before they are re-energized. Other users rely on the second reclosing interval to take care of these types of faults.

Co-ordination Between Reclosing Equipment and Fuses

Many of the users who replied to the questions regarding experience in obtaining successful co-ordination between reclosing equipment and fuses or reclosers and fuses report satisfactory results if care is taken in making the co-ordination study before the equipment is applied.

Table I. Summary of Equipment and Performance Data

Company Number	Type: Service Voltage	Type: Number of Wires	Type: Connection	Type: Grounding	Load (Per Cent): Per Cent Open Wire	Load (Per Cent): Per Cent Cable	Load (Per Cent): Circuit-Miles	Load (Per Cent): Residential	Load (Per Cent): Induction Motor	Load (Per Cent): Synchronous Motor	Equipment: Type	Equipment: Poles	Equipment: Reclosing Cycles (Seconds)	Performance: Per Cent Successful Operations: Initial	Second	Third	Lockout	Most Common Cause of Outage
1	4,160	4	Wye	Multi	95	5	—	90	10	—	Service restorer	3	—	90	—	—	—	—
	12,000	3, 4	Delta, Wye	Multi	95	5	—	90	10	—	Oil circuit breaker	3	15–30 urban 30–60 suburban	90	—	—	—	—
2	16,000	3	Wye	Uni	100	—	—	50	50	—	Oil circuit breaker	3	15–30–45	—	—	—	—	Wind
	11,000	3	Wye	Uni							Service restorer	3	—					
	7,000	4	Delta	Uni							Oil circuit recloser	3	—					
	4,000	4	Wye	Multi	Sensitive ground protection on some 7-kv, 4-kv, 11-kv isolated neutral circuits													
	2,400	3	Delta	Uni														
3	13,000	3	Delta	Uni	100	—	5.8	10	60	30	Oil circuit breaker	3	Instant	100	—	—	—	Lightning
	13,000	3	Delta	Uni	100	—	9.5	40	60	—	3-shot fuses Oil circuit breaker	3	5–65–60	100	—	—	—	—
	13,000	3	Delta	Uni	100	—	33.3	80	20	—	Oil circuit breaker	3	—	60	20	—	20	—
	4,000	4	Wye	Multi	100	—	52.7	—	—	—	Oil circuit breaker	3	50–30–95	80	—	—	20	Wind and trees
	4,000	4	Wye	Multi	100	—	196.8	—	—	—	2-shot fuses 3-shot fuses	—	—	—	83 100	—	17 0	
	2,300	3		Multi	100	—	7.9	25	75	—	Oil circuit breaker	2	15–30–30–60	—	—	—	100	
	13,800	3	Delta	Uni	100	—	11	75	25	—	2-shot fuses		—	50	40	—	10	Lightning
	13,800	3	Delta	Uni	100	—	7	80	20	—	3-shot fuses		—	50	20	20	10	Lightning
	13,800	3	Delta	Uni	100	—	3	90	10	—	3-shot fuses		—	70	10	10	10	Lightning
4	13,800	3	Delta	Uni	100	—	112	75	25	—	Oil circuit breaker	3	—	58	21	8	13	Lightning
	13,800	3	Delta	Uni	100	—	98	75	25	—	Service restorer	3	10–10–30	64	14	5	17	Lightning
	13,800	2	1-phase	Uni	100	—	11	95	5	—	3-shot fuses		—	50	20	20	10	Lightning
	2,300	3	Delta	Iso	100	—	9	60	40	—	Oil circuit breaker	3	15–15–30	90	0	0	10	Lightning
	2,300	3	Delta	Iso	100	—	21.5	80	20	—	Oil circuit breaker	3	15–30–75	25	25	25	25	Lightning
	33,000	4	Wye	Uni	—	—	—	—	—	—	Oil circuit breaker	3	1st 0–18 2nd 20–52	—	—	—	—	Lightning
											Oil circuit reclosers	3						
5	4,500	4	Wye	Multi	90	10	—	—	—	—	Oil circuit breaker	1	Instant 0–30–90 5–30–90 5–30–125	—	—	—	—	Lightning
	Also use one-pole and some three-pole oil circuit reclosers																	
6	7,200	2	Wye	Multi	100	—	35	—	—	—	3-shot fuses			—	—	—	14.8	
	7,200	2	Wye	Multi	100	—	204	—	—	—	Oil circuit reclosers	1	—	—	—	—	12.5	
	4,400	4	Wye	Uni	95	5	1,192	50	50	—	Oil circuit breaker	1	15–30–75	72	7.9	1.4	18.7	—
	Total for 84 circuits—7 per cent of circuits have instant reclosure.																	
7	11,950	4	Wye	Uni	100	—	79	88	12	—	Oil circuit recloser	1	—	—	95	—	5	—
	11,950	4	Wye	Uni	100	—	1,388	88	12	—	Oil circuit breaker multigrounded in 1938–1942	1	0–45–75	76.3	7.4	1.4	14.9	Lightning, trees
	Total of 23 circuits of 12-kv.																	
	23,000	3	Wye	Uni	100	—	263	60	30	10	Oil circuit breaker	3	0–45–75	92.4	2.3	0.6	4.7	Lightning
	11,950	4	Wye	Uni	100	—	150	95	5	—	3-shot fuses		—	55.6	11.1	—	33.3	—
	Nine 12-kv circuits, unigrounded in 1938, multigrounded by 1942.																	
8	13,200	4	Wye	Multi	99.6	0.4	245	55	40	5	Oil circuit breaker	3	0 — —	90.1	4.0	—	5.9	Lightning
	4,160	4	Wye	Multi	99.4	0.6	360	74	25	1	3-shot fuses Oil circuit breaker	3	0 — —	67.6	2.7	8.1	21.6	Lightning
9	All	3, 4	Delta, Wye	All	100	—	5,000	—	—	—	Oil circuit breaker	3	0–15–75	84	10	1	5	Lightning
	Three-pole service restorers and 1-pole oil circuit reclosers used.																	
10	22,000	3	Delta	Isolated	100	—	73	80	20	—	Oil circuit breaker	3	0–30–60	69	4	4	23	Lightning
	11,000	3	Wye	?	100	—	38	87	13	—	Oil circuit breaker	3	0–60–60	53	10	1	36	Lightning
	44,000	3	Delta	Isolated	100	—	62	75	25	—	Oil circuit breaker	3	0–60–60	43	52	2.5	2.5	Lightning
11	4,160	4	Wye	Multi	100	—	80	80	20	—	Oil circuit breaker	3	6–15–75	—	—	—	—	—
	Also use 3-shot fuses, 1-pole service restorers, and 3-pole oil reclosers.																	
12	4,150	4	Wye	Multi	100	—	300	95	4	1	Oil circuit breaker	3	0–20	61	11	—	38	Wild fowl
	(For many old oil circuit breakers.											3	17–20) Also use 3-pole service restorers.					
13	2,300	3	Delta	Isolated	100	—	—	—	—	—	Oil circuit breaker	3	15–30–75	—	—	—	—	Lightning
	11,950	4	Wye	Multi	100	—	—	—	—	—	Oil circuit breaker	3	0–30–75	Approximately 75–90 per cent instantaneously successful.				
	Three-pole oil circuit reclosers used on 12 kv.																	
14	44,000	4	Wye	Multi	80	20	—	30	70	5	Oil circuit breaker	3	10	—	—	—	—	Lightning
15	2,300	3	Delta	Isolated	100	—	—	67	33	—	Oil circuit breaker	3	1–30–90	—	—	—	—	Lightning
	11,000	4	Wye	Multi														
16	110,000	3	Wye	Uni	100	—	66	—	—	—	Oil circuit breaker	3	2	93.6	—	—	6.4	Lightning
	26,400	3	Wye	Uni	100	—	41	—	—	—	Oil circuit breaker	3	1.7	71	—	—	29	Lightning
	8,000	4	Wye	Uni	100	—	190	90	10	—	3-shot fuses	—	—	23	32	—	45	Lightning
	Two 40-ampere and one 75-ampere links used at station with 50-ampere and 60-ampere branch fuses.																	
17	13,200	3	Wye	Uni	100	—	16	50	50	—	3-shot fuses		—	—	—	—	—	Lightning
	4,000	4	Wye	Multi	100	—	25	90	10	—	Oil circuit breaker	3	0–15–60 15–30–60	—	—	—	—	Lightning
	4,160	3	Wye	Uni	100	—	260	65	35	—	Oil circuit breaker	3	10–30–60	—	—	—	—	Wind storm
18	4,160	—	—	—	—	—	100	—	—	—	Oil circuit breaker	—	—	18.2	18.2	13.6	50	Trees

Table I (continued). Summary of Equipment and Performance Data

Company Number	Type: Service Voltage	Type: Number of Wires	Type: Connection	Type: Grounding	Per Cent: Open Wire	Per Cent: Cable	Circuit-Miles	Load (Per Cent): Residential	Load (Per Cent): Induction Motor	Load (Per Cent): Synchronous Motor	Equipment: Type	Equipment: Poles	Equipment: Reclosing Cycles (Seconds)	Performance: Per Cent Successful Operations: Initial	Second	Third	Lockout	Most Common Cause of Outage
19	All	—	—	—	100	—	4,000 10,000	Transformer Distribution			—	—	—	85	10	3	2	Lightning, tree
20	4,150	4	Wye	Multi	100	—	17.5	100	—	—	Oil circuit breaker	3	10-20-60	—	—	—	—	—
	4,800	3	Delta	Isolated	96.3	3.7	111.5	62	38	—	Oil circuit breaker	3	10-20-60	—	—	—	—	—
	Also use 3-pole oil circuit reclosers.																	
21	4,160 13,000	4	Wye	Multi	100	0+	3,000	75	20	5	Oil circuit breaker Older oil circuit breaker	3 3	0-15-60 10-30-36	74	9	2	15	Lightning
	6,600	3	Delta	Isolated	100	—	1,100	—	—	—	Oil circuit breaker	3	?	70	13.5	1.5	15	Lightning
22	2,080 4,160	3	Delta	Isolated	90	10	2,150	—	—	—	Oil circuit breaker	3	15-30-60 7-7-7 20-20-20	80			20	—
23	All	—	—	—	100	—	—	Induction motor dominates		pre-	Oil circuit breaker 2-, 3-shot fuses	3	0-30-60	80	5	1	14	—
24	4,000	4	Wye	Uni	90	10	2,000	20	50	30	Oil circuit breaker	3	0-10-150 6-60-150	87	3	1	9	—
	Three-pole service restorers and oil circuit reclosers used.																	
25	12,000	4	Wye	Multi	99	1	800	100	0+	—	Oil circuit breaker	3	0-30-60	80	15	4	1	—
26	33,000	3	Delta	Petersen coil	100	—	31	30	40	30	Oil circuit breaker	3	Instant	95	—	—	—	Lightning
27	2,300	3	Delta	Uni	100	—	Short	—	—	—	Oil circuit breaker	3	0-20-40	80	20	—	1	—
	Three-pole service restorers and 3-pole oil circuit reclosers used.																	
28	12,000	4	Wye	Multi	100	—	5	100			3-shot fuses		—	—	—	—	0	Trees
29	34,500	3	Wye	Uni	100	—	1,500	50	40	10	Oil circuit breaker 2-shot fuses	3	0-15-85	75	20	0+	5	Lightning, trees
	12,000	4	Wye	Multi														
	2,400	3	Delta	Uni														
30	4,160	4	Wye	Multi	88.8	11.2	647	18.3	50.3	5.6	Oil circuit breaker	3	15-45-90	52.8	2.2	3.4	41.6	Lightning
31	6,900	3	Delta	Isolated	100	—	100	80	20	—	2-, 3-shot fuses		—	—	—	—	1	Lightning, wind
	One-pole service restorers used.																	
32	34,500	3	Delta	Uni	100	—	26	95	5	—	Oil circuit breaker	3	5-15-30	—	—	—	—	Lightning
	34,500	3	Delta	Uni	100	—	29	85	15	—	3-shot fuses		—	70	5	5	20	Lightning
	11,000	4	Wye	Multi	100	—	42	90	10	—	Oil circuit recloser	3	3-3-3	80	10	5	5	Lightning, wind
33	4,225	4	Wye	Multi	95	5	2,643	43	57	—	Oil circuit breaker	3	0-30-60	80	7-8	3-4	8-10	Trees
34	4,000	4	Wye	Multi	100	—	400	70	30	—	Oil circuit breaker	3	15-45-90	—	90		10	Lightning, trees
	2,300	3	Delta	Isolated														
35	4,000	4	Wye	Uni	90	10	1,186	65	30	5	45 circuits 35 circuits	oil circuit breaker oil circuit breaker	1 3	15-30-90	75	10	4	11	Lightning
	Have some 2-shot fuses.																	
36	4,000	4	Wye	Multi	85	15	250	65	32	3	Oil circuit breaker—1-, 3-phase 2-, 3-shot fuses		Instant only	75	—	—	25	Lightning
	5,000	3	Delta	Isolated	100	—												
37	4,500	4	Wye	Multi	40	60	550	45	55	—	53-oil circuit breaker 86-oil circuit breaker	1 3	0-30-60	50	23.5	5	21.5	Wind
	Night loading				90		90	10	—	—								
	4,800	3	Delta	Isolated	96	4	12,500	25	45	5	Oil circuit breaker	3	15-60-60	80	5	1	14	Lightning
	4,800	3	Delta	Isolated	100	—	870	100	—	—	Oil circuit breaker	3	15-60-60	84	2	0	14	Lightning
	Has sectionalizing fuses.																	
38	4,800	3	Delta	Isolated	100	—	985	98	2	—	Oil circuit breaker	3	0-15-30-30	75	18	1	6	Lightning
	Has sectionalizing fuses.																	
	4,800	3	Delta	Isolated	100	—	345	100	—	—	Oil circuit breaker	1	5-5-5-5	97	2	—	1	Lightning
	Has sectionalizing fuses.																	
	4,800	3	Delta	Isolated	100	—	768	100	—	—	Oil circuit breaker	1	1-1-1-1	93	5	—	2	Lightning
	4,000	4	Wye	Multi	100	—	125	85	15	—	Oil circuit breaker	3	0-30-60 15-30-75	50	—	—	50	Lightning
	22,000	3	Wye	Uni	100	—	12	95	5	—	3-shot fuses		—	—	—	—	100	—
	Fuses unsatisfactory—to be replaced by oil circuit breaker.																	
39	22,000	3	Wye	Uni	—	—	22	85	13	2	Oil circuit breaker	3	0-30-60	30	—	—	50	Lightning
	6,600	3	Delta	Isolated	100	—	31	75	25	—	Oil circuit breaker	3	15-30-90	—	—	—	100	—
	6,600	3	Delta	Isolated	100	—	23	75	25	—	3-shot fuses		—	—	100		0	Lightning
	2,300	3	Delta	Isolated	100	—	20	75	25	—	3-shot fuses		—	—	100		0	Lightning
	4,000	4	Wye	Multi	100	—	2	95	5	—	Oil circuit breaker	3	15-30-75	98	—	—	—	Lightning
40	2,400	3	Delta	Isolated	100	—	4,800	80	15	5	3-shot fuses Oil circuit breaker	3	0-30-90 4-30-90 30-60-90	54	28	14	4	Lightning
	4,160	4	Wye	Multi														
	4,800	3	Delta	Iso, uni														
	7,200	3	Delta	Iso, uni														
	(30-60-90 reclosing cycle for synchronous motor loads)																	
	2,400	3	Delta	Isolated	100	—	13,800	75	15	10	2-shot fuses 3-shot fuses Oil circuit breaker		0-30-60	70	20	5	5	Lightning
	4,160	4	Wye	Multi														
	4,800	3	Delta	Isolated														
41	8,330	4	Wye	Multi	(Uses time delay for initial reclosures for synchronous motor loads as requested by customers.)							3						
	7,200	3	Delta	Isolated														
	12,500	4	Wye	Multi														
	11,000	3	Delta															
	14,400	3	Delta	Isolated														

Difficulties which have been encountered in making these applications are:

(*a*). Trouble in obtaining co-ordination with ground relays except in such cases where fuses of low current rating are applicable.

(*b*). Failure to obtain co-ordination between service restorers with instantaneous trip and fuses unless the fuses are of such low current rating that they will blow at currents near the pickup value of the restorer.

Conclusions

As the result of this survey, the following conclusions may be reached:

1. In terms of circuit-miles, immediate initial reclosing is most commonly used for residential loads and 15-second initial reclosing for induction motor loads.

2. Successful initial reclosing was reported for approximately 75 per cent of the trip outs. The second and third reclosures will be successful in approximately 15 per cent of the cases, and lockout can be expected in ten per cent of the cases.

3. Present reclosing equipment appears to meet the requirements of most of the users except that a necessity for changes as noted previously in available oil circuit reclosers or service restorers is indicated.

4. Circuits should be re-energized in 0.5 to 2 seconds if the dropping of induction motor loads is to be avoided.

5. No trouble from restriking of the arc was reported with immediate reclosure with normal speed breakers. Some users, however, feel that an interval of 0.5 second should be provided.

6. The possibilities of using immediate reclosing for motor circuits should receive further study, as there are indications that the advantages of immediate reclosing can be extended to include a much larger percentage of motor circuits than is now being done.

References

1. Engineering report 47 of the Joint Subcommittee on Development and Research of the Edison Electric Institute and the Bell Telephone System. Volume V, July 1941, pages 239–71.

2. Factors Contributing to Improving Electric Service by Means of High-Speed Switching and Utilization of Stored Energy, J. T. Logan, J. H. Miles. AIEE Transactions, volume 60, 1941, December section, pages 1012–16.

3. Experience With Oil Circuit Reclosers on REA Systems, L. M. Moore, B. O. Watkins. AIEE Transactions, volume 62, 1943, August section, pages 531–5.

Appendix. AIEE Committee on Automatic Stations Questionnaire on A-C Automatic Reclosing Equipment

Please give data for each set of circuit and load conditions for which different reclosing practice is used.

Reporting company.....Location.....

A. Circuit and Load Data

Voltage.....Three-wire.....Four-wire.....Delta.....Wye.....

Isolated.....Unigrounded.....Multigrounded.....

.....per cent overhead.....per cent cable

Load....per cent residential....per cent induction motor....per cent synchronous motor

B. Equipment

Repeating fuses two-shot..... three-shot.....

Circuit breaker.....pole (single or three) with.....reclosing cycle. Specify most usual reclosing cycle as: instantaneous; 0–30–60 seconds; 15–30–75 seconds; 0–30 seconds, and so forth.

Service restorer.....pole (single-pole or three-pole)

Oil circuit reclosers.....pole

Protective relay..... (instantaneous overcurrent, time delay overcurrent, and so forth)

Does the equipment automatically change the relaying time after first, second, or third reclosure? ..... Give brief description of sequence of operation.

C. Experience Data

Approximate.....years.....circuit-miles

Successful reclosures for reclosing cycle given above

Initial immediate .....per cent. Initial time delay.....per cent

Second.....per cent. Third.....per cent. Lockout.....per cent

What has been found to be the most convenient way of determining the number of first, second, or third reclosures?

Most common cause of outage cleared fast enough for successful immediate initial reclosing. Lightning..... trees..... ....

Reclosing cycle found to be particularly suitable for:

(*a*). Lighting loads.....

(*b*). Synchronous motor loads.....

(*c*). Induction motor load.....

(*d*). Combined motor and lighting loads.....

(*e*). Selective operation with branch circuit fuses.....

(*f*). Selective operation with branch circuit reclosers or service restorers.....

D. General

Do available reclosing relays meet operating requirements, or is some modification in the operating cycle desirable? If so, please give suggested modification.

Do available oil circuit reclosers or service restorers meet operating requirements, or is some modification desirable? If so, give suggested modification. Also give reasons for preferring the single- or three-pole device.

Does the lack of the self-resetting feature in the case of reclosing fuses result in excessive lockouts? What steps do you take (such as patrolling) to keep the number of lockouts to a minimum?

What has been found to be the *maximum* time that the circuit breaker may remain open during a reclosing cycle, without dropping any appreciable part of the motor load? State whether load is predominately induction or synchronous.

Give operating data which indicate *minimum* time that circuit breaker may be reclosed with assurance that fault arc path has been given sufficient time to deionize. In answering this question, consideration should be given to the effect of counter electromotive force from synchronous machines (connected to the feeder) which tend to sustain the fault arc while the circuit breaker is open.

What has been your experience in obtaining successful co-ordination between reclosing equipment and fuses, the latter being located in some subdivision of the feeder?

What has been your experience in obtaining successful co-ordination between oil circuit reclosers or service restorers, and fuses, the latter being located in some subdivision of the feeder?

Any additional comments:

This questionnaire is limited to stub feeders which are energized from one source only and which do not require voltage checking devices, synchronizing relays, and so forth.

A Capacitance Bridge for Determining the Ratio and Phase Angle of Potential Transformers

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Synopsis: A capacitance bridge for the calibration of instrument potential transformers up to 300 kv is presented in this paper. This bridge provides measurements which are correct within 0.1 per cent on ratio and 3 minutes on phase angle. There are within the bridge arrangements for testing its accuracy as determined by the stability of its component arms. It is particularly desirable to have this means of self-testing if transformers are to be tested in a laboratory which does not have extensive standardizing facilities. Further advantages beyond accuracy for standardization purposes are flexibility and ease of operation for production testing, and low cost and small volume as compared to a high-voltage resistance potentiometer.

IN the determination of ratio and phase angle of potential transformers, measurements are required which are correct within 0.1 per cent on ratio and three minutes on phase angle. Such measurements are made on transformers with voltage ratings as low as 110 volts and as high as 161 kv. It is probable that higher voltages may be used in the future.

A capacitance bridge has been developed for this purpose. This bridge is connected first as a Schering Bridge in order to establish the relative impedance of its arms; then it is connected one part to the primary winding of an instrument potential transformer and the other part to the secondary winding of the transformer in order to determine the ratio and phase angle between the windings of the transformer.

This method of measuring the properties of transformers may be compared to the resistance potentiometer method[1,2] and to previous proposals for capacitance bridge methods.[3,4,5] The most conspicuous advantage of this method over the resistance-potentiometer method is the reduction in weight and space required. The advantage over previous proposals of a capacitance bridge is provision for reconnecting the bridge in order to establish its accuracy in place.

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Performance

A bridge of this design was installed in the transformer section of the Pittsfield works' laboratory and used in conjunction with the 132-kv shielded resistance potentiometer[1] already there. It was operated for a period covering both the winter and summer seasons.

The relative size of the capacitance bridge made it very attractive, as it required 200 square feet of floor space whereas the resistance potentiometer required 900 square feet. The saving of factory space allows a saving in testing because it facilitates the handling of transformers during this stage of manufacture.

Transformers have been tested throughout the range 110 volts to 161 kv. The extreme flexibility of the capacitance bridge was an appealing point to the operator. A 1400:1 ratio could be checked as easily as a 20:1. The change from one voltage or ratio to another could be done without changing high-voltage taps on the equipment. Odd ratios were just as simple to measure as were the integral ratios.

A 50 micromicrofarad high-voltage compressed-gas capacitor was used for ratios down to 10:1. Below 10:1 ratio a 200-micromicrofarad shielded air capacitor was used. This combination of standard capacitors provided good sensitivity over the whole voltage range.

After this experience a permanent installation was decided upon. A new bridge was built and installed and has been in use for over a year. This bridge provides measurements which are correct within 0.1 per cent on ratio and three minutes on phase angle throughout the voltage range used thus far. The bridge voltage rating is 300 kv, and no difficulty is expected in extending measurements to this voltage.

The Bridge Circuit

This bridge has two resistance arms and two capacitance arms as shown in Figure 1*a*. Two of these arms, R_3 and C_3, are fixed in magnitude. C_3 is a shielded gas capacitor for high-voltage use. The other arms, R_4 and C_4, are continuously adjustable. If R_4 is adjusted to a conductance $\sqrt{n}$ times that of R_3, where n is the ratio of the transformer to be tested, the bridge can be balanced by adjusting C_4 to a capacitance $\sqrt{n}$ times that of C_3. Now suppose C_4 and C_3 interchanged and the transformer connected so that the high-voltage winding is connected to C_3 in series with R_4 and the low-voltage winding to C_4 in series with R_3, Figure 1*b*. The smaller capacitance, C_3, is now in series with the larger conductance, R_4, but the voltage applied to this combination is n times that applied to the larger capacitance in series with the smaller conductance. Thus the voltage drop across R_3 is again equal to that across R_4 and the bridge again in balance excepting a small phase shift explained in Appendix I. If the transformer ratio differs slightly from n, the small change in R_3 or R_4 required to restore balance is a measure of this departure. Used in this manner, the bridge gives evidence of its own stability before each measurement on a transformer. This self-standardizing feature is particularly desirable if transformers are to be tested where extensive standardizing facilities are not available.

A detailed explanation of this bridge circuit for measuring the ratio and phase angle of a transformer is developed in Appendix I. The bridge connections finally arrived at are shown in Figure 4. In this figure R_{2a} is a bridge resistance arm adjustable from 9,900 ohms to 10,110 ohms, set at 10,000 ohms when the ratio correction factor is unity. The adjusting dials are marked directly in ratio correction factor. Adjustment for phase angle is made by changing C_{2a}, and C_{2a} is marked in such units that it reads directly in phase angle at 60 cycles when R_{2a} is at 10,000 ohms. Departure from direct reading in phase angle at other values of R_{2a} may be corrected by reference to a curve in any case and is minimized by care in the design of the $R_{2a}C_{2a}$ arm of the bridge so that no correction is required on the greater portion of transformer tests.

R_{2a} in the bridge is made of a conductance decade; that is, of resistors connected in parallel by a switching sequence, marked in terms of $\sqrt{n}$ where n is the nominal transformer ratio. The

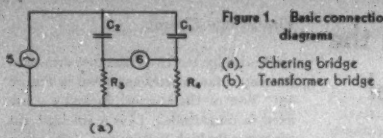

Figure 1. Basic connection diagrams

(a). Schering bridge
(b). Transformer bridge

conductances of the principal resistors in R_{34} are 1, 2, 2, 5, 10, 20, 20, and 50 times the conductance of the 10,000-ohm setting of R_{33}.

Note particularly that errors in the ratio of R_{33} to R_{34} are doubled in their effect on the determination of potential transformer ratio. This is not a serious disadvantage because the conductance decade arrangement, in which most of the conductance of R_{34} is made up of steps of $^1/_3$, 1, and 2 times 10^m where m is an integer, lends itself especially to precise and accurate determination of the ratio between R_{33} and R_{34}.

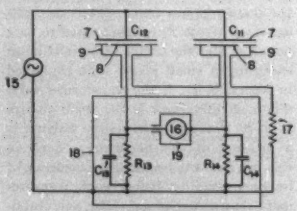

Figure 2. Connection diagram of Schering bridge including shielding

Capacitor C_{12} in Figure 4 is of fixed capacitance and suitable for use at high voltage. C_{11} is an adjustable low-voltage capacitor with worm drive for precise setting while balancing the bridge. Any difference in dielectric loss angle between these capacitors appears double as an error in transformer phase-angle measurement. This error will not exceed one-quarter minute of angle so long as the capacitor at C_{11} is kept fairly dry.[7]

The Bridge

The high-voltage capacitor which constitutes one bridge arm, C_{12} of Figure 4,

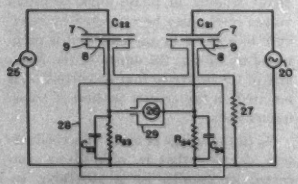

Figure 3. Connection diagram, capacitance bridge for comparing two voltages

has shielded concentric cylindrical electrodes operated in carbon dioxide at about 100 pounds per square inch gauge pressure. Figures 5 and 6 show the construction. The essential properties and advantages of standard capacitors constructed in this manner have been set forth elsewhere[6,7] and will merely be summarized here.

(*a*). Change of dimensions with voltage is calculably negligible.

(*b*). Change of dimensions with temperature and its effect on capacitance is calculable.

(*c*). Change of capacitance with alignment is calculable; thus, limits within which it is negligible may be established.

(*d*). The maximum dielectric loss angle encountered in such capacitors is small as compared to usual phase-angle accuracy requirements, that is, much smaller than one minute at 60 cycles.

With respect to factor *b*, the massive tank by its thermal slowness limits temperature gradients inside the capacitor. A steady-state temperature change of five degrees centigrade or a change in the temperature difference between electrodes of two degrees centigrade is required to produce 0.01 per cent effect on measured ratio. In order to produce this effect, these changes must occur between the standardization in terms of bridge resistors and the measurement on the transformer, a matter of a few minutes at most.

This capacitor may be operated at voltages up to 300 kv rms.

The other parts of the bridge are housed in the case shown in Figure 7 and Figure 8. Note at the top of Figure 8 the parallel plate capacitors used at C_{11} of Figure 4. One of these has a worm drive which allows adjustment to 0.005

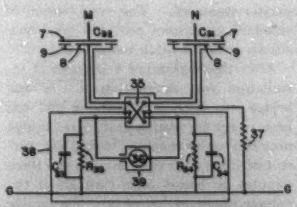

Figure 4. Connection diagram of bridge for measuring the ratio and phase angle of potential transformers

micromicrofarad. The other two are of fixed capacitance and may be switched into circuit to extend the capacitance range. All have plates supported from a guard structure with the solid insulation shielded from the field between plates.

Dielectric loss angle of these capacitors is ordinarily less than 0.00002 or four seconds of angle. The accuracy of phase-angle measurement depends upon the maintenance of a small loss angle. Proof of such maintenance is obtained from the standardization balance of the bridge before each measurement. Any change in C_{34} of Figure 4 from the customary value

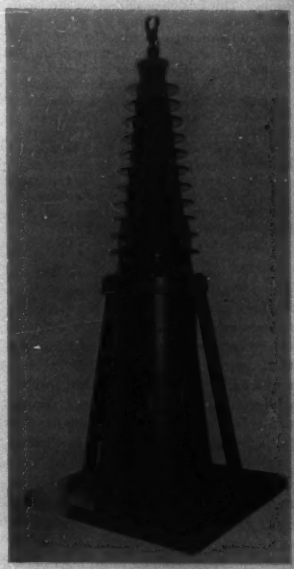

Figure 5. Compressed-gas capacitor, 300 kv

is evidence that the relative dielectric loss angle of the air capacitors has changed. In practice, only the low-voltage capacitor changes, and it changes only because of humidity and dirt.[7] Ordinary care in maintenance will avoid such changes.

The resistance arms of the bridge are partly visible in Figure 8, behind the galvanometer amplifier case. The principal resistors are of manganin. The one micromho steps are of advance alloy, and the smaller conductance decades are carbon resistors. These latter serve only for fine adjustment of the $\sqrt{n}$ arm, hence errors of several per cent are allowable.

The galvanometer and its amplifier are in a case within the main bridge case.

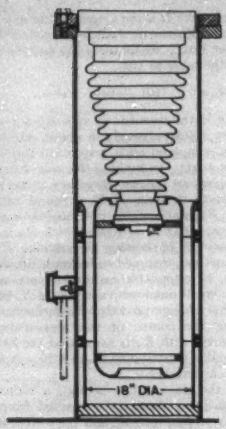

Figure 6. Cross section of the 300-kv capacitor

The capacitance between cases is a part of C_{34}.[5] It is not affected by switching connections and therefore not a factor in the accuracy of the bridge.

The lower part of the bridge case has relays which connect an auxiliary power supply for the calibrating balance of the bridge and which may be used for remote control of high-voltage switching.

Figure 7. Bridge for measuring ratio and phase angle of potential transformers

Measurement Procedure

The operation of the bridge is as follows:

1. Set ratio-correction-factor dials at 1.0000; set phase-angle dials at a value determined by the ratio of the transformer to be tested; set $\sqrt{n}$ dials at the square root of the nominal transformer ratio; then turn selector switch to "calibrate."

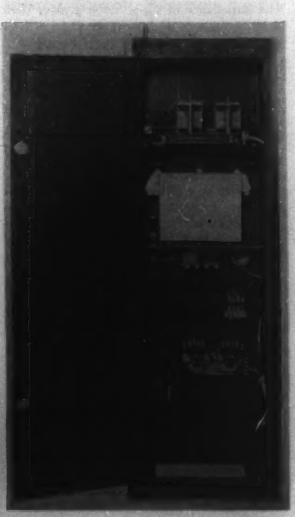

Figure 8. Back view of the bridge, case open

2. Apply power to calibrating circuit, and balance the bridge by adjusting the low-voltage air capacitor C_{31} and the capacitance C_{34} of Figure 4.

3. Connect transformer to be tested and turn selector switch to "measure."

4. Apply power to transformer and balance the bridge by adjusting the ratio-correction-factor and phase-angle dials at each desired burden and excitation. Ratio correction factor of the transformer is read directly from the dials. Phase angle is read directly from the dials on tests at 60 cycles. At other frequencies the dial reading must be multiplied by the ratio of the test frequency to 60.

Standardization of the Bridge Resistance Arms

Accuracy of the transformer-ratio measurement rests on the accuracy with which resistance ratio between the bridge arms is known. The ratios of the various R_{31} settings to R_{32} are preferably determined in place using a step-by-step procedure which imposes conditions equivalent to those of actual use. A schedule has been established whereby these ratios can be determined after about one hour's systematic work. This procedure has been confirmed by measuring the resistances separately in terms of resistance standards which in turn have been compared to standards maintained at the National Bureau of Standards.

Changes in the present bridge since the initial standardization have been confined to the expected trivial slow drift in relative resistance of the arms, but it must be recognized that a significant change is possible at any time, although it is not expected. Therefore, the operator should be alert for any irregularity in the "calibrate" balance before each measurement and, in addition, should carry out occasionally the schedule established for determining resistance ratio between the arms. That this can be done without external standards is an advantage.

Summary

A bridge has been developed for measuring the ratio and phase angle of instrument potential transformers. The measurements are correct within 0.1 per cent in ratio and three minutes in phase angle. The bridge rating is 300 kv, but actual use thus far has been limited to tests at 161 kv and below. This limit was imposed by the transformers requiring test, and extension of tests to higher voltage, when transformer design requires it, offers no difficulty.

Appendix I

Consider Figure 1a in which C_1 and C_2 indicate capacitance while R_1 and R_4 indicate electrical resistance. If an alternating current is supplied by generator 5, the condition for no resultant potential across a circuit element 6, such as a galvanometer, is that:

$$C_1/C_2 = R_4/R_1 \qquad (1)$$

When it is sought to realize the circuit of Figure 1a in practice, it becomes necessary to take into account any departure of actual capacitors from being pure capacitance and any residual inductance or capacitance of the resistors which may be used where resistance is indicated in the figure. In addition, capacitance from conducting parts of the apparatus to earth and to other apparatus not shown may affect the distribution of current from the generator. Figure 2 shows diagrammatically the arrangement of apparatus which results when these factors are considered.

In Figure 2, C_{11} and C_{12} are capacitors each having electrodes 7 and 8 and further electrodes 9 which entirely surround electrodes 8, excepting the exposure of electrodes 8 to electrodes 7. Electrodes 7 and 8 are supported from electrodes 9 by separate pieces of solid insulating material so that no solid insulation lies in the region between electrodes 7 and 8. This region is filled with air or other gas.

R_{13} indicates the resistance of a resistor. The residual inductance or capacitance of this resistor, expressed as capacitance, together with any deliberately introduced capacitance, is shown as C_{13}. Similarly, R_{14} and C_{14} indicate another resistor with its associated capacitance, whether deliberately introduced or accidental. A galvanometer or other voltage-detecting means is shown at 16. A conducting case 18 may enclose circuit elements 13, 14, and 16 to shield them from external electric field. If the galvanometer 16 is shielded by a shield 19 connected as shown in the figure, the capacitance from shield 19 to case 18 must be included as part of the capacitance C_{14}. There are also other means of successfully shielding galvanometer 16.

Suppose alternating current is supplied by generator 15, and suppose further that the circuit elements are adjusted until no voltage exists at galvanometer 16. Suppose that impedance 17 has been adjusted until no voltage exists between conductors 8 and 9 of the capacitors. Under these circumstances the current through the impedances indicated by the subscripts 13 and 14 will be exclusively the charging current through the direct capacitance between plates 7 and 8 of capacitors C_{12} and C_{11}, respectively. The necessary and sufficient relationships between the impedances indicated by the subscripts 11, 12, 13, and 14 are:

$$C_{11}/C_{12}=R_{13}/R_{14} \tag{2}$$

and

$$R_{14}(C_{13}+C_{11})-R_{13}(C_{14}+C_{12})=0 \tag{3}$$

combining equations 2 and 3 gives the simple relation between the impedances indicated by subscripts 13 and 14:

$$R_{14}C_{14}-R_{13}C_{13}=0 \tag{4}$$

If, now, an imperfect dielectric is introduced between the plates 7 and 8 of one capacitor, say capacitor 12, the angle A by which the vector representing the charging current of this capacitor lags that representing the charging current of a pure capacitance is given by the expression, valid for angles so small that the angle expressed in radians approximately equals the tangent of the angle:

$$A=\omega(R_{14}C_{14}-R_{13}C_{13}) \tag{5}$$

where $\omega=2\pi$ times the frequency in cycles per second. This is the Schering bridge (Thomas bridge) commonly used for dielectric measurements.[10,11]

Consider now Figure 3, similar to Figure 2 except that generator 25 supplies current to capacitor C_{22} while separate generator 20 supplies current to capacitor C_{21}. Suppose that these generators have voltages in phase with one another, but that the voltage of generator 25 is n times the voltage of generator 20. The condition for no voltage at galvanometer 26 is:

$$\frac{nR_{23}}{1+j\omega R_{23}C_{23}}=\frac{R_{24}}{1+j\omega R_{24}C_{24}} \tag{6}$$

$$\frac{R_{23}}{1+j\omega R_{23}C_{23}}+\frac{1}{j\omega C_{22}}=\frac{R_{24}}{1+j\omega R_{24}C_{24}}+\frac{1}{j\omega C_{21}}$$

The expanded statement of the relation between the impedances indicated by the subscripts 21, 22, 23, and 24 necessary to satisfy this condition is unwieldy in length. If the impedances are selected so that

The impedance of C_{21} is much greater than R_{24}

The impedance of C_{22} is much greater than R_{23}

$\omega R_{23}C_{23}$ is much less than 1

$\omega R_{24}C_{24}$ is much less than 1

certain approximate relations are sufficient. These follow:

$$C_{21}/C_{22}=nR_{23}/R_{24} \tag{7}$$

$$R_{24}(C_{24}+C_{23})-R_{23}(C_{22}+C_{23})=0 \tag{8}$$

If there is a difference B in phase angle between the voltages from generators 25 and 20, small enough that the angle expressed in radians may be assumed equal to the tangent of the angle,

$$B=R_{24}(C_{24}+C_{23})-R_{23}(C_{22}+C_{23}) \tag{9}$$

It is evident that the bridge of Figure 3 may be used for the measurement of the ratio and phase angle between voltages such as the primary and secondary voltages of an instrument potential transformer, since equations 7 and 9 enable the calculation of ratio and phase relationship from the observed values of C_{21}, C_{22}, R_{23}, C_{23}, R_{24}, and C_{24}.

If such comparison is to be made with great accuracy, it is necessary to consider the accuracy with which the value of the several circuit elements may be known. Consider equation 7. Resistors are commonly prepared of alloy wire little enough affected by temperature variations and of such permanence that the resistance may be known within 0.01 per cent. Air capacitors are not made readily with such accuracy. Consider now equation 9. This equation is based on equality of phase angle between current and voltage in the two air capacitors represented by C_{21} and C_{22}. This condition may be realized within some few seconds of angle. However, uncertainties in the value of C_{22} and C_{24} may lead to errors in usual practice nearly as large as one minute of angle in the determination of the phase angle B.

It would be desirable to determine the ratio and phase angle between two voltages in terms of the more accurately definable quantities, that is, the resistances R_{23} and R_{24} and the purity of the capacitances at C_{21} and C_{22}. For a method of accomplishing this end, refer to Figure 4. In this figure, C_{22} is a fixed air or gas capacitor, shielded and guarded in the fashion previously described. C_{21} is an adjustable air capacitor so shielded and guarded. It is required of C_{21} that once it is adjusted, it shall, if not touched, remain constant in direct capacitance between its electrodes 7 and 8 until the measurements described hereafter are completed. It is not required that any particular adjustment shall be reproducible at a later time. Resistances R_{23} and R_{24} shall be adjustable so that

$$R_{23}/R_{24}=r \quad (10) \quad \text{where} \quad r^2=n \tag{11}$$

and n is the nominal or approximate ratio of two voltages, nearly in phase, which are to be compared with respect to ratio and phase angle. In making this adjustment it is convenient but not necessary to have the resistance in ohms of R_{23} a round number while R_{24} is adjustable to secure the ratio r. The capacitance associated with R_{23} is, for convenience in showing the working of this test method, assumed to be made up of two parts, an adjustable calibrated portion C_{23} and a small unknown capacitance X, which will not change provided R_{23} is unchanged during the course of the measurements. Similarly, with R_{24} is associated the known adjustable capacitance C_{24} and the unknown fixed capacitance Y.

In the use of this method, a source of alternating voltage is connected from M and N to G, Figure 4, and the switch 35 is positioned to connect C_{21} to R_{24} and C_{22} to R_{23}. C_{23} is adjusted to some arbitrary small capacitance; R_{24} is adjusted in accordance with equation 10; then C_{24} and C_{21} are adjusted until galvanometer 36 indicates equality of the voltages across R_{23} and R_{24}. By analogy to equation 2, this is true when

$$C_{21}/C_{22}=R_{23}/R_{24} \tag{12}$$

whence, from equation 10,

$$C_{21}/C_{22}=r \tag{13}$$

From analogy to equation 4

$$R_{24}(C_{24}+Y)-R_{23}(C_{23}+X)=0 \tag{14}$$

whence

$$C_{24}+Y=(R_{23}/R_{24})(C_{23}+X) \tag{15}$$

using equation 10

$$C_{24}+Y=r(C_{23}+X) \tag{16}$$

Now the switch 35 is changed so that C_{21} is connected to R_{23} and C_{22} to R_{24} while separate voltage sources are connected from M to G and from N to G. The voltage at M is n times that at N and in phase with that at N. Now by analogy with equation 7, equality of voltage across R_{23} and R_{24} will be secured when

$$C_{21}/C_{22}=nR_{24}/R_{23} \tag{17}$$

substituting from 10 and 13, $r=(n/r)$ therefore, $n=r^2$ which is simply equation 11. Thus, R_{23}, R_{24}, C_{23}, and C_{21} need not be changed if the ratio between voltages at N and M is actually n. However, C_{23} or C_{24} will have to be changed, as may be seen from analogy to equation 8. Suppose C_{23} is unchanged, but C_{24} is changed to a new value C_{24}' in order to secure equality of voltages across R_{23} and R_{24}:

$$R_{24}(C_{24}'+Y+C_{23})-R_{23}(C_{23}+X+C_{21})=0 \tag{18}$$

$$C_{24}'+Y=r(C_{23}+X+C_{21})-C_{23} \tag{19}$$

Subtract equation 16

$$C_{24}+Y=r(C_{23}+X) \tag{16}$$

$$C_{24}'-C_{24}=rC_{21}-C_{23} \tag{20}$$

but, from equation 13

$$rC_{21} = r^2C_{22} = nC_{12} \qquad (13)$$

therefore,

$$C_{24}' - C_{24} = (n-1)C_{12} \qquad (21)$$

Note that X and Y need not be known. Any departure of the ratio between the two voltages from the assumed value will require a proportionate change in either R_{22} or R_{24}. Similarly, if the two voltages do not agree in phase, either C_{22} or C_{24} will need to be changed. Specifically, if C_{24} is changed to C_{24}' as indicated in equation 21, any further change necessary will be due to a phase difference D, expressed in radians.

$D = \omega R_{24}$ times the change in C_{12}

or

$D = \omega R_{24}$ times the change in C_{24}, whichever is changed.

In the operation of the bridge for instrument potential-transformer calibration, it has been found most convenient to mark C_{12} in minutes of angle at 60 cycles. Then the calibrating balance of the bridge (as a Schering bridge) is made with C_{12} set at such a value (in minutes at 60 cycles) as that required for the change from C_{12} to C_{12}' when the arms are reversed.

$$C_{22} - C_{22}' = [(n-1)C_{12}]/r \qquad (22)$$

This makes C_{22}' the capacitance marked "0 minutes" on the dial.

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Carrier-Current Differential Protection for Transformer Banks

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WHEN carrier current was first applied to protective relaying of the directional type, it consisted of a simple telegraph channel. Subsequent developments have expanded the capabilities to the extent that each carrier channel for pilot relaying now may provide one or more of the following additional services:

1. Simplex telephony for testing or emergency use.
2. Telemetering or load control.
3. Supervisory control of unattended substations.
4. Remote control of circuit breakers or sectionalizing switches.
5. Transferred tripping to provide differential protection for transformer banks used with only a low-voltage circuit breaker.

Situations frequently arise where a power-system planning or designing engineer finds it necessary to install a power transformer with only a low-voltage breaker. This is particularly true under present conditions where new plants must be served with as little additional equipment as possible. In many cases, this resolves into extending a line from an existing station or bus and terminating it with a transformer bank. Another common arrangement is to tap the transformer bank on an existing line, using only a low-voltage breaker.

Both of these arrangements present a problem for the relay engineer, especially the protection of the transformer bank. The standard line relays give some protection for transformer faults but usually cannot be set for the required sensitivity. Some conventional type of differential relay can be used to detect faults in the transformer and cause tripping of the local low-voltage breaker, but this does not clear the fault. If the fault is on the low-voltage winding, or close to the ground end of the high-voltage winding, there is a good possibility that the remote relays will not have the required sensitivity to trip the remote circuit breaker.

In this case it becomes necessary to convey the tripping indication from the local differential relay to the remote circuit breaker, and this can be accomplished by pilot-wire circuits, carrier-current channels, and so forth. Another method of tripping the remote breaker is to place a fault on the high-voltage side by means of a shorting switch which will produce a fault of sufficient magnitude to operate the remote trip relays. It is the purpose of this paper to describe a simple and reliable method of remote tripping transmitted over a carrier-current pilot relaying channel.

The accepted practice for carrier-current pilot relaying channels is to operate them as simple telegraph channels which transmit carrier to hold a blocking relay in the nontrip position at the ends of the line section. In this type of operation, the channel is in use only a short portion of the time for relaying or test, and it is customary to include modulation equipment to provide a testing or emergency telephone channel. The addition of the remote tripping function to the carrier-current channel improves the use factor and requires less critical material than other methods.

As previously stated, the pilot relaying equipment for protection of the transmission line operates on a blocking principle. The carrier transmitter is maintained in a stand-by condition at all times, with full voltage on plate and cathode-heater circuits, but the screen grids of the transmitter tubes are maintained at a negative potential with respect to the cathodes, which prevents the transmitter from operating. When the contacts of the fault-detector relays operate, the screen grids immediately change to a positive potential, and the carrier transmitter is started. If the fault is within the range of protection of the relays, the directional relays operate to re-establish

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the grid bias on the transmitter tubes and stop carrier transmission. As soon as the carrier blocking signal is removed, the receiver relay is free to complete the circuit through the contacts of the tripping fault-detector relay to the trip coil. After the blocking signal is removed, the receiver relay drops out in about five milliseconds. The completion of the trip circuit operates a seal-in relay which bypasses all other relay contacts and holds the trip circuit energized until the circuit breaker opens.

It can be seen that with this mode of operation, momentary blocking of the receiver relay by interference produced by extremely short-time transients, such as lightning, will have no appreciable effect on the successful operation of the relaying system.

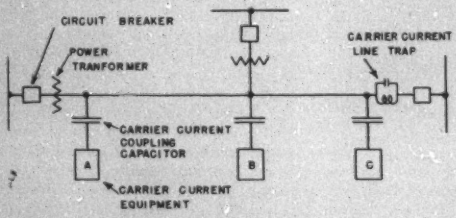

Figure 1. One-line schematic diagram of typical remote-trip installation

A. Transmits and receives remote-trip signal
B. Transmits and receives remote-trip signal
C. Receives remote-trip signal

When the blocking system is inverted and a *tripping* signal is sent instead of a blocking signal, it will be noted that an operation of the receiver relay by interference cannot be tolerated. Since there are no remote fault detectors which recognize the fault in the transformer bank, it is necessary to entrust to the carrier-current channel the complete job of tripping the remote breaker.

There are many possible methods of conveying this remote tripping information over the carrier-current channel. Some of these may be summarized as follows:

1. Keyed code. This requires no change in carrier set but requires mechanical coder and decoder or selector mechanism.

2. Modulating tone applied to carrier. This requires an oscillator at the transmitting end and a filter unit at the receiving end.

3. Frequency shift of carrier. This requires a means for shifting the carrier frequency at the transmitter end and a special receiver to recognize this shift in frequency either by a heterodyne method, by a balanced discriminator, or by simply shifting carrier far enough to avoid interference from the normal carrier frequency.

4. Some combination of the foregoing methods, such as keyed modulation, modulation applied as frequency modulation, or combinations of more than one modulating tone.

Operating time is an important consideration in any protective relaying scheme, and this speed must be accomplished with satisfactory accuracy. Where this tripping signal is being superimposed on an existing channel, also having high speed requirements, it becomes necessary to make some compromise in order to obtain simplicity of equipment. Insofar as the transformer bank is concerned, the tripping time should be instantaneous to limit the extent of the damage. In many cases where no provision is made for tripping the remote breaker, the transformer fault will remain on the system until a telephone call can be put through to the remote station, or events will follow their usual course with the fault spreading until the current is sufficient to operate the remote line-protection relays.

Between the two extremes of instantaneous tripping and not tripping at all, a maximum relay time of 0.5 second was selected as a reasonable value which would make it possible to obtain the required accuracy with simple equipment.

The keyed-carrier method was first investigated since it had the outstanding advantage of requiring no changes in the carrier equipment. There are various factors, however, which offset this advantage since the complications are transferred to the selector mechanism, and these complications increase as the tripping time is decreased. Where this remote tripping function is to be added to an existing carrier channel of older design equipment which did not provide modulation facilities, or a receiver with a satisfactory audio output, there is considerable merit in an arrangement which employs keyed carrier and a selector, although the relay time is increased.

One such arrangement may consist of a transmitter which sends short impulses at a uniform rate of ten per second, and a selector mechanism which will reject any other combination of dots, dashes, or spaces in transmission. Ten consecutive impulses must be received in order to trip the breaker, and the code is either repeated several times or the transmitter runs continuously until the hand-reset auxiliary tripping relay associated with the transformer differential protection is reset. The ten-impulse code thus is repeated several times to assure tripping, since any interference received just before or during a tripping signal may mix up the code and prevent operation. The continued-impulse type of code provides a short recovery time after such an interference.

The carrier-frequency shift or frequency-modulation method requires a separate receiver and introduces some complexity in the transmitter. While this arrangement has been applied in certain cases, the audio-tone method is easily added to existing equipment and has some very practical advantages.

After due consideration of the various points of each method, the arrangement using an audio modulating tone was selected to convey the tripping information over the carrier channel. Factors influencing this decision were:

1. The necessary speed of operation could be obtained with the required selectivity.

2. The equipment could easily be added to the standard equipment for pilot relaying.

The design of this modern carrier equipment provided the necessary modulator and a receiver with satisfactory audio-output characteristics, while the oscillator and filter units were in production as components of other standard carrier-current equipment.

The details of the over-all operation of this system may be summarized as follows: At the sending end, the occurrence of a fault in the transformer bank operates the differential relay, which in turn operates a hand-reset multicontact auxiliary relay. One set of contacts on this relay starts carrier transmission, and another contact starts the audio-oscillator unit which usually is adjusted for a frequency of 3,000 cycles. This 3,000-cycle tone modulates the transmitter output. At the receiving end of the carrier channel, the receiver demodulates the incoming signal, and the resulting 3,000-cycle audio tone is fed into the input of the filter unit. The filter unit consists of a vacuum tube operated as a relay tube with sufficient negative bias to prevent plate current from flowing under stand-by conditions. The tuned circuit is connected across the input to the control grid and adjusted to 3,000 cycles. This arrangement attenuates all frequencies except the 3,000-cycle signal, which, when applied to the grid of the relay tube reduces the bias voltage, and plate current flows in the relay circuit to operate the audio relay. The audio relay

is provided with an adjustable time delay of 0.1 to 0.5 second to further improve the over-all selectivity of the equipment by preventing operation on nearby lightning strokes or other causes of interference. When this relay operates, it energizes a hand-reset auxiliary which trips the circuit breaker.

Details of Equipment

The basic carrier equipment for pilot relaying consists of a transmitter-receiver unit, a coupling capacitor to couple the signal to the high-voltage line, and a line trap to terminate the protected line section in a high impedance to prevent the short-circuiting of the carrier channel by external line-to-ground faults on the coupling phase. The equipment is built in units of a standardized width of 19 inches, and a panel space height that is a multiple of 1¾ inches. The following paragraphs give a general description of each of the various units which are used to make up a given assembly.

Transmitter-Receiver Unit

This standard equipment is designed for operation directly from either a 125-volt or 250-volt station storage battery, with a carrier frequency range of 50 to 150 kilocycles. The transmitter employs five type-25*B6G* tubes in a master-oscillator power-amplifier circuit. The receiver employs two tubes, one 25*A7G* as a detector and audio tube, and one 25*B6G* as a relay tube.

An important feature of the receiver is the separation of the telephone function from the pilot relaying function. The incoming carrier signal is rectified by a diode unit in the 25*A7G* tube. The resulting voltage is filtered slightly and fed to the grid of the relay tube. This circuit is designed to have a limiting characteristic so that the relay current is essentially constant for all signals within the working range of the receiver. Since changes in incoming signal voltage produce practically no change in plate current, it is obvious that this tube cannot be used to obtain audio output from the receiver. For this reason the multisection type-25*A7G* tube is used since it contains another section which can be used as an audio amplifier. A portion of the a-c voltage developed across the diode-rectifier load resistor is coupled to the input circuit of this amplifier. This arrangement provides the desired characteristics for the relaying and the telephone function and permits obtaining sufficient audio output to operate the audio relay units used for the remote-tripping function.

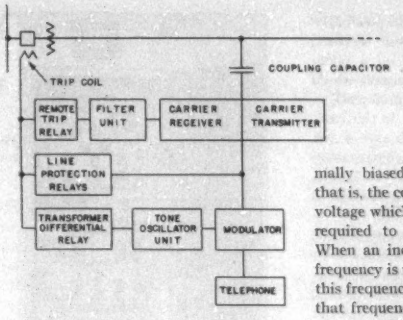

Figure 2. Block diagram of carrier-current equipment showing arrangement for pilot relaying, sending and receiving remote-tripping signal, and telephone

Modulator Unit

The modulator unit employs two type-25*B6G* tubes in a push–pull amplifier circuit, the output of which is applied to the screen grid circuits of the transmitter to modulate the carrier-current output. The 3,000-cycle tripping signal from the oscillator is fed directly into the modulator unit ahead of the speech input volume control in order to obtain independent control of both of these functions. A 3,000-cycle filter is added to the microphone circuit to eliminate this frequency from the voice circuit. This filter has negligible effect upon the intelligibility of the voice signal since the bulk of the voice frequencies lie below 2,000 cycles.

Audio-Oscillator Unit

The oscillator unit required for the remote tripping signal usually is adjusted to 3,000 cycles. This adjustment is made by changing the capacitor combinations and moving the iron core in the inductance. The oscillator tube is a twin triode, one side of which is used for the oscillator, while the other side serves as a buffer amplifier to prevent changes in frequency due to changes in external loading. A filter is provided on the power supply to eliminate the possibility of any ripple on the station battery voltage supply from being amplified and fed into the modulator unit. The oscillator is normally in a stand-by condition and is started by completing the cathode circuit to the negative power supply. The output voltage of the oscillator is adjustable to control the degree of modulation applied to the carrier wave.

Filter Unit

The filter unit is designed to work with the audio-oscillator unit, and contains two tuned circuits which are adjustable over the same range as the oscillator unit. Each tuned circuit is connected across the input circuit of a relay tube which is normally biased so that no current flows; that is, the control grid is maintained at a voltage which is more negative than that required to cut off the plate current. When an incoming signal of the proper frequency is received, the circuit tuned to this frequency offers a high impedance to that frequency and permits a voltage to appear on the control grid circuit of the asscciated relay tube. This voltage is alternating, of course, and on the positive swings the control grid voltage is made positive thus causing plate current to flow in the relay circuit.

Sockets are provided on the filter unit for mounting two relays. In this case, the relay associated with the 3,000-cycle tone is located on the switchboard while the relay for other tone is mounted on this unit.

Relay Unit and Accessories

The adjustable time delay on the tripping relay is obtained by means of a small auxiliary relay with a copper slug on the coil, and the time is adjustable by varying the air gap and spring tension. This relay is picked up normally, and the time is obtained on the drop-out. The coil of this time-delay relay is energized from the station battery, through normally closed contacts on the audio receiver relay which is mounted in the same enclosing case. When an audio signal is received to produce tripping, the audio receiver relay picks up, thus interrupting the coil circuit of the time-delay drop-out relay, and at the same time it closes one set of contacts in the circuit to the type-*HEA* hand-reset auxiliary relay. When the time-delay relay closes its contacts, it completes the circuit to the *HEA* and trips the circuit breaker.

Every protective device requires provision for test and maintenance, and this is provided for by a test switch, a milliammeter to read the audio-receiver-relay current, and a signal lamp to show when a tripping signal is being received. The purpose of this signal lamp is to warn the operator that the *HEA* relay should not be reset since the tripping signal is still on the line.

Some Details of Operation

Whenever two or more services are placed on any transmission medium, it be-

comes necessary to consider the possibility of interference between these services. The addition of telephony on a pilot-relaying channel is a good example where it is a simple matter to give preference to the more important service. In this case, fault-detector relays at each end of the channel are arranged to take control away from the telephone function if necessary. The remote-tripping function presents a different problem, since in this case no indication of the fault exists at all terminals; in fact, that is the exact reason the transferred tripping must be done. Since normally only one carrier frequency is used for both transmission and reception, the local receiver is desensitized by the strong signal produced by the local transmitter, and although it is possible to hear the incoming 3,000-cycle tone in the telephone receiver, it is of insufficient strength to operate the audio relay. Upon hearing this audio tone, it is a natural impulse for the operator to shut off his carrier transmitter since he assumes that the remote station is calling him, which of course is correct. As soon as the local transmitter is stopped, the audio signal increases greatly in volume and trips the circuit breaker. This difficulty could be avoided by using two different frequencies for transmission and reception, but this would necessitate changes in the method of protection on lines having more than two terminals and introduces certain other undesirable complexities.

There is no interference between the operation of the normal pilot relaying equipment and the remote-tripping equipment, since a transformer fault of sufficient magnitude to cause the pilot relays to operate will not require the assistance of the remote-tripping equipment.

Overmodulation of any carrier transmitter should be avoided since it produces harmonics in the audio as well as the radio frequency output. Accidental overmodulation of the transmitter at 1,500 cycles will produce some second harmonic output of the receiver at 3,000 cycles which may be sufficient to operate the tripping relay. To eliminate this possibility, the second audio-filter unit is tuned to 1,500 cycles and arranged to desensitize the 3,000-cycle filter when a 1,500-cycle tone is received. With the input adjusted for normal speech, the 1,500 cycles present in the telephone feature is insufficient to operate the 1,500-cycle relay.

Figure 3. Carrier-current pilot relaying equipment, with oscillator and filter unit for transformer differential protection, in cabinet for outdoor mounting

Other Uses

In cases where there are three terminals of carrier on a line section, each set being equipped with remote-trip transmitter and receiver equipment, it will be found very useful to use a 1,500-cycle tone for telephone calling by using a simple code for each station. By this method the alarm bell will not operate at the third station while the other two stations are using the phone.

In cases where the remote circuit breaker is equipped with high-speed reclosing equipment, it is desirable that this feature should function only when the breaker trips for transmission-line faults. The relay connections should be arranged so that it is impossible for the automatic recloser to operate in any case where the circuit breaker is tripped by the transformer differential relay. After the faulty transformer has been removed from the circuit, a 1,500-cycle tone may be used to release the lockout thus restoring the breaker to normal operation.

Cases frequently occur where it is required to control a single remote circuit breaker or disconnect switch at an unattended substation. From the previous description it is evident that the remote-trip equipment can readily be adapted for this type of service, and by the addition of the proper auxiliaries an indication of the position of the remote device also can be obtained.

Installations

New system interconnections, where the tie points are at different operating voltages, and new loads tapped on existing lines have resulted in a considerable number of installations of this type of equipment. These applications have included the following arrangements:

A. Single circuit line with transformer at one end.

B. Double circuit line with transformers at one end.

C. Single circuit three-terminal line with transformer at one terminal.

D. Single circuit three-terminal line with transformers at two terminals.

E. Single circuit three-terminal line with transformers at all three terminals.

Critical-Material Conservation in Induction-Motor Manufacture

HENRY M. HOBART
FELLOW AIEE

Present Importance of Avoiding Over-Motoring

IN several articles which recently have appeared in the technical press, it has been indicated that, in the interests of the war effort, standards of reliability in service may have to be compromised. As an example, one author advocates that electric motors should, in some cases, be utilized with continuous loads 25 per cent greater than has been considered good practice heretofore, "particularly if the ambient temperature within which the motors are expected to operate, is less than the recognized permissible maximum of 104 degrees Fahrenheit." That author adds the caution that this may not be practicable in all cases, since other factors than the continuous thermal rating sometimes determine the motor size. Then he adds: "However, in most war plants, such cases are relatively few."

Proposed Plan

In the present paper, careful consideration is given to the rating-up amounts which are desirable in the case of induction motors, in view of the acute urgency of conserving critical metals. The conserving of *copper* is of chief importance, but by the plan here presented there is effected at the same time a great saving of other metals. The plan recommended in this paper does not involve any compromise in "standards of reliability in service."

Predominating Importance of Induction Motors

Of all electric motors the induction motor is the one of which the greatest quantity is required by industry. If, for the total number of induction motors which will be manufactured in the year 1943, the per-horsepower consumption of copper and other metals can be reduced by 25 per cent, as compared with heretofore practice, and by plans not involving delays for redesigning and retooling, thousands of tons of copper and other metals will be saved and can be made available for direct military purposes. It is the intent of this paper to describe means for effecting this large saving without the occasioning of any delay in the production program of the manufacturers of induction motors.

The heretofore (and present) basis of rating of induction motors, so far as it relates to the limiting service temperatures, has been extremely conservative, as the result of a determination to ensure

1. Large margins of safety.
2. High service dependability.
3. Long life.

Furthermore, the basis was adopted a good many years ago, when the customarily used insulating materials of reasonable cost and ready application were considered inadequately heat resisting to withstand higher temperatures for long service periods. In recent years, wide experience has been gained with various insulating materials which will endure subjection to much higher temperatures for long periods of service. While usually these materials are more expensive than the early thermally inferior materials, several amongst them are manufactured in sheets, tapes, and all other required forms, so that they may be substituted without any redesigning of the motors, dimensional or otherwise. This substitution is an important feature of the conservation project described in the present paper.

Under the comfortable conditions of peacetime, no appreciable headway was made with rating-up proposals, notwithstanding the known availability of these better insulating materials. Now it is apparent that the conservation of copper and other metals is of such vital importance that all will co-operate eagerly in seeking for sound plans for the accomplishment. It is important to make the change-over with a minimum of delay. Any dimensional changes in the design and in the manufacturing specifications inevitably would interrupt smooth and rapid large-scale production and would be accompanied by disastrous delays.

Reduction of the Per-Horsepower Weight Achieved by Rating Up

Consequently it appears desirable that the *dimensions* of the present low-temperature—but nevertheless highly developed and excellent—designs shall be retained and that the reduction of the per-horsepower weight shall be effected by rating up the motors at present being manufactured. The only change in their construction will be the substitution of the high heat-resisting insulation but of precisely the same *dimensions* as the insulation heretofore used.

33 Per Cent Increased Rating

This plan will permit of increasing the rated output by 33 per cent, and reducing by 25 per cent the per-horsepower weight of copper and other metals required in the construction.

Precedents for Employing Higher Service Temperatures

Railway motors, totally enclosed motors, and the insulation of the rotors of turbogenerators long since have been standardized on the basis of much higher permissible service temperatures than those allowed for general-purpose induction motors. Contrary to predictions these three (and other) higher-temperature products have experienced no undue life impairment, when suitable heat-resisting insulations have been skillfully employed. Similar success will attend the use now proposed of higher service temperatures for the induction motors.

Present Severe Service Conditions Render High Stalling Loads Particularly Desirable

Let us now consider how the case stands with respect to limitations to rating up, other than thermal limitations. Leaving the motor design just "as is" (that is, on the present low-temperature basis), most sizes, particularly those for low speeds, will not have an adequately conservative stalling-load margin by the time their 33 per cent greater (new) rated loads are reached. Unless we do something about it, the margin between the (new) rated load and the original stalling load often will be too small, particularly for the rough and severe conditions of present-day production. The motor will stall at a

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lower load, the greater the drop in the supply-line voltage, and vice versa. It is important to realize that, with the high loading of power circuits now becoming usual, (and the necessarily associated great voltage drops) and with the intense incentive to accomplish tasks in the shortest possible time, there frequently will result the imposition upon the driving motors of much more severe voltage drops and momentary load peaks than are apt to be experienced in normal times. Evidently, while our rating-up plans will not encounter any difficulties as regards liability of the occurrence of breakdowns due to overheating, there is the need that there still shall be provided very liberal reserves of torque, over and above the torque corresponding to the increased rated load, so as to remove all likelihood of production interruptions from motor stalling. Such motor stalling would be more intolerable, in view of the emergency circumstances, than ever it could have been in peacetime.

Inherent Relations Between Temperature Limits Imposed, Stalling-Load Requirements, Periodicity, and Rated Speed

This matter of ensuring that the induction motor should possess a momentary stalling load liberally in excess of the rated load (while sometimes, particularly in the case of low-speed motors, it caused the motor designer to depart from otherwise best proportions) did not constitute a major problem, so long as the limiting service temperatures were required to be very low. That condition tended strongly (in almost all sizes and types), to make the permissible service temperature the limit of rated output. But now, the boot is on the other leg. Going over to the endorsement of higher service-temperature limits for induction motors brings us right up face to face with the condition that the momentary stalling load henceforth usually will constitute the actual limitation on the rated load for which a motor always can be relied upon to be liberally adequate in service. Fortunately, it has become recognized as good practice to employ for induction motors the highest practicable speed. For a given periodicity, the inherent stalling load (broadly speaking) is greater, the greater the rated speed. Obviously, this paper is concerned chiefly with the conditions in 60-cycle systems. For lower periodicities (such as 25 cycles), the provision of an adequately high stalling load rarely will impose a limit on the rating, except for extremely low-speed motors.

The stalling load can be increased by increasing the voltage at the motor's terminals. But the supply-circuit voltages have become so thoroughly standardized, and the motor designs have been standardized for so long a time for these particular supply-circuit voltages that, in order to provide at the motor terminals a voltage higher than the standard supply-circuit voltage, it has been necessary (1) to use special step-down transformers with secondary voltages higher than standard, or else (2) to boost the secondary voltage by interposing an induction regulator between the supply circuit and the terminals of the motor. But, while the higher terminal voltage will increase the motor's stalling load, it will impair both the power factor and the efficiency at light loads. A long time ago, the proposal was made (and used, to a certain extent), to provide a low terminal voltage at light loads and gradually higher voltages with increasing load (so as to provide the best characteristics at *all* loads) by equipping the transformer secondary with several taps and with means for transferring automatically the induction motor's terminals from tap to tap as the load increases. Tap-changing-under-load transformers could, of course, be used, the change being effected by an automatic regulator responsive to load changes. Feeder regulators, or special or complicated transformers, however, would take the gilt off the gingerbread and leave us using as much (or even more) per-horsepower weight of copper and other metals (for induction motor plus regulator) as for the original low-temperature (and high-copper) motors with their high reserves of stalling torque.

Desirability of Retaining (At Any Rate, for the Duration) The Present Excellent Designs of Induction Motors

Actually, it is the volts per turn which we desire to increase, in order to increase the stalling torque. The simplest way to increase the volts per turn obviously is to decrease the number of turns and increase the magnetic flux. This, however, means new designs and the inevitable great delays for development and testing. (*Even then* there will be incurred a certain amount of impairment of the motor's light-load characteristics.) Furthermore, after years of continual improvements effected in the course of many redesignings, most induction-motor manufacturers (on the basis of the standardized low-temperature limits) have arrived at lines of very well balanced designs in which the polar pitch, and the core length, and the volts per turn for each particular rated output and speed and voltage and periodicity are so nicely balanced as to provide about the best practicable combination of high power factor, efficiency, starting torque, and reasonably low starting current.

Clearly, it is of prime importance to salvage these many fine designs (at any rate, for the duration) and thus also have the great advantage of eliminating the enormous and time-consuming task of developing new lines of induction motors to fit the higher permissible service temperatures and decrease the per-horsepower weight of copper and other metals. That is not a task which possibly could be accomplished in a few weeks (or even in less than a good many months), and also it would be likely to require considerable retooling. For each of the usual horsepower sizes there are required designs for various voltages and speeds and degrees of enclosure and other subclassifications. A fresh start would require, in this case, the laborious and time-consuming development and testing of many dozens of new designs of induction motors.

Thus it appears that an effective plan, not involving any delays, for reducing the per-horsepower weight of copper and other metals required in induction-motor manufacture is to continue building the present induction motors without any changes except that which has been indicated, namely, the use of the better insulations with high heat-resisting properties. The plan requires the provision of some *external* means, or some *externally* located material, for increasing considerably the stalling torque so that it shall be liberally adequate for the conditions of the increased rating, and for the more intense and strenuous conditions of service consequent upon the war effort. Especially in war plants the certainty of freedom from even the slightest service interruptions is of vital importance. Already it has been explained that, for this requirement of increased stalling torque, it will be necessary to provide some means whereby any instantaneous or sustained overloads shall be accompanied by an adequate increase in the volts per turn. Furthermore, it will be desirable that the means employed shall embody features contributing toward improving the motor's light-load characterisics by *decreasing* the volts per turn at light loads.

Use of a Hookup With Series and Shunt Capacitors

As an effective means for providing that the volts per turn shall automatically

increase with increasing load, there may be employed a plan which was conceived 21 years ago. At that time, there was no urgent need for providing induction motors with this feature of variable volts per turn. Also in other respects, the proposal was regarded as premature. But the present greatly changed conditions indicate the method to be particularly timely and appropriate. The following is a description of it.

Description

Three series capacitors are interposed between the three-phase supply circuit and the three terminals of the windings of the induction motor. In addition, there are provided across the motor terminals three shunt capacitors. Either the series capacitors are designed for a current equal to the current in the motor's windings or they may be located in the secondaries of three small transformers whose primaries are interposed in series with the three motor terminals.

The shunt capacitors are proportioned for a current equal to the lagging component of the motor current at its rated load (that is, they are proportioned for complete compensation for unity power factor at rated load). Consequently the power factor is leading for all loads from no-load up to the rated load. (So far as concerns the employment of shunt capacitors with induction motors, this already is widely practiced, and it so improves the economics of the supply system as usually to amply justify the outlay for the required shunt capacitors.)

The Purpose of the Series Capacitors

For the purposes of the project described in this paper, the series capacitors are so proportioned as to decrease and increase the motor's terminal voltage by desired amounts below and above the constant voltage of the supply circuit. For loads less than some selected value (rated load, in the case being considered), the lagging current into the motor is overcompensated by the leading current in the shunt capacitors. The resultant current from the supply circuit, being a leading current, causes the motor's terminal voltage to be less than the supply circuit's voltage, because of the voltage drop which is occasioned in a capacitor when a leading current flows through it. From rated load upward, the opposite result is obtained, and the motor's terminal voltage increases as the load increases, because the current through the series capacitors is lagging.

Illustrative Example

As an example, let there be considered the case of a three-phase 60-cycle 4-pole 480-volt squirrel-cage general-purpose induction motor, which, for the heretofore usual low-temperature practice, is rated at 75 horsepower. At its rated voltage of 480 volts, such a motor will carry double load (that is, 150 horsepower) without stalling. By providing this 75-horsepower motor with the capacitor hookup recommended in this paper, it may be rated up to 100 horsepower and will then, without stalling, carry momentary overloads up to 200 horsepower. Of the three series capacitors for this purpose, each will have such capacitance as to increase the motor's terminal voltage from the supply circuit's constant voltage of 480 volts up to 555 volts when the load has increased from rated load of 100 horsepower, up to twice the rated load namely, 200 horsepower. Conversely, these series capacitors serve to decrease the motor's terminal voltage down to values below 480 volts, to an extent dependent upon the amount by which the load decreases below the rated load.

Aggregate Improvements Thus Provided

This decrease of the voltage at low loads and its increase at high loads also serve to increase the low-load and high-load efficiencies above the values which can be realized with constant voltage maintained at the motor terminals for all loads. Not only are the improvements resulting from these various effects, accompanied by increased power factor and efficiency at all loads, but also they endow the (motor plus capacitors) combination with a leading characteristic for all loads up to the rated load, and they afford a means for increasing the stalling load above that attainable in a constant-voltage design and consequently also a means for increasing the rated output. Finally, there is thereby effected an important decrease in the per-horsepower weight of critical material required in the motor's construction.

Rating of Required Capacitors

It has been stated already that the provision of shunt capacitors for obtaining power-factor improvement long since has been admitted quite generally to justify their cost. The economies resulting therefrom extend throughout the entire system over which the induction motors are supplied and relate both to reduced capital outlays and reduced losses in all the material interposed between the source and the induction motors supplied therethrough. The further-mentioned advantages of greater motor efficiency at all loads, increased rated output, and decreased per-horsepower weight of critical metals undoubtedly will be agreed to justify the outlay for the series capacitors. In the cited example of a 100-horsepower motor with a stalling load of not less than 200 horsepower, the required amount of series capacitance comes to 30 kva, provided in three 10-kva capacitors interposed betweeen the supply-circuit terminals and the motor terminals. These series capacitors boost the system voltage from 480 volts at a load of 100 horsepower, up to 555 volts at a load of 200 horsepower, the currents per phase for these two loads being respectively 100 amperes and 220 amperes.

Series-Capacitor Compounding Transformer

When, in the interests of decreasing the losses in the distribution circuit, load-center location close to the induction motor is provided for the step-down transformer (or group of transformers), it will be practicable, often, to decrease the outlay for the series capacitors by locating them in the high-voltage side of the step-down transformers. Thus, for the example chosen (a 480-volt induction motor), and a primary voltage of 4,800 volts, the voltage stress across each series capacitor would then be much more favorable for the design of the series capacitors with respect to decreasing their cost. This plan amounts to providing *compounding* transformers. For the particular case of the illustrative example, the secondary voltage of the (nominally) 480-volt transformer would increase with the load from a value of, say, 415 volts at no load of the induction motor up to 555 volts just below the occurrence of the motor's stalling load.

Development of Power Capacitors

In the period from 1919 to 1922, when this project and other *Series*-capacitor power projects were proposed (although *shunt* capacitors already were sufficiently common in power applications to be quite familiar to power engineers), the idea of a *series* use of capacitors with *power* apparatus was considered by many power engineers to be of questionable soundness and in need of demonstration. Another objection was that power-capacitor manufacture was then only in its

early beginnings. Paper of the desired quality and with the necessary freedom from objectionable constituents remained to be developed. The paper needed to be of extreme thinness so that weaknesses at various places in its extent could be averaged out by the super position of several paper layers between adjacent conducting foils. Processes of evacuation and impregnation still left much to be desired. The demand for capacitors for power applications was out of all proportion too small to enable the cost to be satisfactorily decreased by large-scale mass production. Furthermore, those were days of extravagance and waste. The conditions were the reverse of propitious for attracting interest to a proposal which was regarded as both premature and unimportant. That, admittedly, then was the case with this proposition.

In 1924, however, presumably out of a spirit of amiable tolerance toward persistent and reprehensible importunacy, the scheme was made the subject of a patent application, and patent 1,595,937 of 1926 finally emerged. It is probable that the method never has been employed in service. The present emergency circumstances and the timely advantages which the project provides would seem to be providentially opportune.

Summary

There follows a list of some of the attendant circumstances and of the advantages which may be gained by the use of the project:

1. Thoroughly reliable power capacitors now are manufactured in great quantities by many firms.

2. Cost is much lower than in 1922.

3. By simple constructions embodying the external-pressure principles by means of which Hochstadter has demonstrated that the service insulation strength of underground high-voltage cables can be doubled for a given insulation thickness, the per-kva cost of power capacitors readily may be decreased much further.

4. By the use of power capacitors as a simple adjunct the power factor and efficiency of an induction motor may be considerably improved for all loads, light and heavy, and the stalling load may be much increased. Throughout a considerable range of load, system economies associated with a leading current will be obtained.

5. Higher-temperature service operation now is recommended, and the rating of the present highly-developed, low-temperature, induction motors may be increased by 33 per cent, without requiring any delays, since no re-designing is involved. There is required merely the substitution of the high heat-resisting insulation now available.

6. The project will permit of the conservation of considerable quantities of critical materials as the result of decreasing by 25 per cent, the per-horsepower weight of the motors.

The recommendations made in this paper (and the means proposed) for increasing by 33 per cent the present service rating of general-purpose induction motors is more conservative than many will realize. It is anticipated that, when the electrical industry has acquired more confidence in the adequacy of the available better insulations (as regards withstanding heat deterioration), practice will advance to the extent of permitting even higher service temperatures and securing further reductions in the per-horsepower weights of copper and other metals which it is of such critical importance to conserve. But rather than jeopardize the acceptance of his recommendations, the author has refrained from advocating still greater amounts of service-rating increase.

WPB L-221

In a note on page 81 of the February 1943 issue of ELECTRICAL ENGINEERING, the War Production Board's general conservation order L-221 is stated to contain a provision whereby the horsepower of a new electric motor shall not exceed the requirements of the specific job for which the motor is purchased. Compliance with this and other conservation provisions contained in the order (so far as it relates to general-purpose motors) are expected to conserve annually about 6,000 metric tons of copper and 55,000 metric tons of carbon steel. In the present paper attention has been confined to the specific case of general-purpose induction motors, and means particularly applicable thereto are recommended for effecting savings of amounts of critical materials which should exceed the amounts envisaged in WPB L-221. These recommended means also will improve the operating conditions as respects efficiencies, power factors, stalling loads, and reduced rate of life impairment.

Ambient Conditioning

In conclusion, attention well may be called to the present advanced state of development of systems for the conditioning of factory and workshop premises. While consideration for the health and efficiency of the personnel quite rightly is the main objective, it is not out of place to consider also the extent to which the rate of life impairment of the *motors* may be decreased by decreasing the ambient temperature in the midst of which the motors' existences are spent. The 68 degrees Fahrenheit which is beneficial for the personnel should be capable of being closely approached, even in the immediate surroundings of the motors, rather than any approach to the temperature of 104 degrees Fahrenheit now assumed in the rating regulations as being a temperature of likely occasional occurrence. It will, of course, be necessary to take into account the fact of the relatively great amounts of heat being developed in the motors as a consequence of their losses. But by simple applications of fundamental principles of local air circulation, accentuated when desirable by surface vaporization methods of heat transfer, the desired 68 degrees Fahrenheit temperature should be capable of close approach at all seasons and localities and even at distances of relatively few inches from the external surfaces of the motors.

A New High-Speed Balanced-Current Relay

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NEED for a high-speed, balanced-relay current which will not function when the first half-cycle current is deficient in one of the two parallel circuits being protected, has been shown by the recent paper "The Effect of Current-Transformer Residual Magnetism on Balanced Current or Differential Relays."[1] This is the result of high residual magnetism of the current transformer caused principally by the d-c component of an offset wave on previous short circuits.

A high-speed, induction-cylinder-type relay has been developed in which the operating-coil circuit has an inherent delay of approximately one cycle, due to the time constant of a resonant circuit. The restraining torque of the relay is effective in a small fraction of a cycle and is obtained by using a flux-shifting copper tube acting as a lag ring or short-circuited secondary.

Application

Several AIEE papers[2,3,4] have presented the development and application of high-speed relays in which the speed of operation was recognized as an essential characteristic in obtaining greater system transient stability. Since the standard time for circuit-breaker operation was reduced to eight cycles or less, this meant that relay operating times of approximately one or two cycles were necessary to realize the full benefit of this circuit-breaker operation. In designing a new relay, one must recognize the increasing demand for high speed, but its attainment must not be accompanied by sacrifice of either selectivity or reliability.

The balanced-current relay is most generally used to provide protection against current unbalance at the source end of parallel untapped transmission lines, where the unbalancing is occasioned by phase-to-phase or ground faults in either line. It may also be used for a similar protection at the receiving end of parallel lines provided there is an additional source of power supply (other tie lines, generators, or synchronous apparatus) at the receiving end which will increase the fault current in the defective line at least 10 to 25 per cent. The schematic one-line diagram, Figure 1, illustrates this application and emphasizes its limitation for the load end protection where the currents in breakers *A* and *B* would be equal.

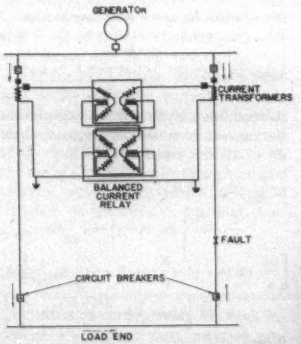

Figure 1. Schematic one-line diagram illustrating balanced-current protection of parallel lines

Operating requirements for the new relay cannot be reduced from that followed on existing high-speed, balanced-current relays. This means that satisfactory protection for simultaneous faults on the parallel lines, protection on single-line operation, high-speed auxiliary switches or interlocking relays, operation with bus tie breaker, proper functioning during magnetizing inrush, and current-transformer characteristics are items for consideration. Besides these factors tending toward faulty operation, if improperly handled, there have been recorded occasional false trippings which, until recently, were without satisfactory explanation.[1,5] Now, since it has been shown that residual magnetism in the current transformer may result in false operations with existing high-speed relays, a relay has been designed to function correctly although this undesirable, yet unavoidable, current-transformer characteristic exists.

Description and Operation of Relay

The relay unit with eight-pole, induction-cylinder construction previously presented before the Institute[6] is inherently a high-speed device and readily lends itself to balanced-current operation. The available poles permit both the operating and restraining functions to be accomplished in a single unit. The single relay unit protects only one phase of one line and the relaying of both lines is accomplished with a two-element relay shown in Figure 2. For complete balanced-current protection at the generating end of two parallel lines, three relays are sufficient; two for phase-to-phase faults and one for ground faults.

Six of the available eight poles are used, and their location is shown in Figure 3. The left three coils, denoted by *A* and *B*, are the operating coils while the right three coils, *C* and *D*, provide the restraining torque. These torque-producing elements exert their force on a common rotor in opposition to one another to give a balance. The production of this torque is like that of a wattmetric

Figure 2. Single-phase high-speed balanced-current relay

Paper 43-117, recommended by the AIEE committee on protective devices for presentation at the AIEE national technical meeting, Cleveland, Ohio, June 21-25, 1943. Manuscript submitted April 29, 1943; made available for printing May 18, 1943.

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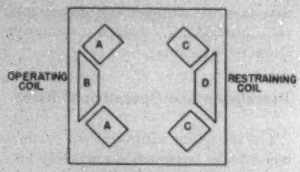

Figure 3. Coil locations in a single element of the balanced-current relay

element, and in the case of Figure 3, the coils B and D produce rotor currents which react with the flux of their adjacent coils. The torque magnitude is a function of the product of the flux and the sine of the angle between them. From this relation and the connections of Figure 1 it is obvious that some means must be provided to obtain a phase displacement between the pole flux for both the operating and restraining circuits.

For the restraining circuit a flux-shifting copper tube is employed. This method is similar to one used in current-polarized directional units of the induction-cylinder construction. The vector diagram, Figure 4A, gives an approximate time-phase relation for the restraint circuit showing the flux shift in the corner poles (C of Figure 3).

For the operating function, the necessary flux shift is obtained by means of a floating circuit. The purpose of this flux-shifting method is to permit the use of a tuned circuit in which the delayed current build-up retards the action and the operating torque. As can be observed from Figure 6, the impetus imparted to the relay by the difference current occurs during part of the first cycle depending on the nature of the fault, and the delay required does not detract from the high speed (Figure 8) of the relay.

The floating circuit is composed of a many-turn coil to replace the copper tube and tuned with a capacitor mounted inside the relay case. The circuit constants can be modified with the use of a reactor, resistor, or both, as shown in Figure 5, to control the magnitude and time. For

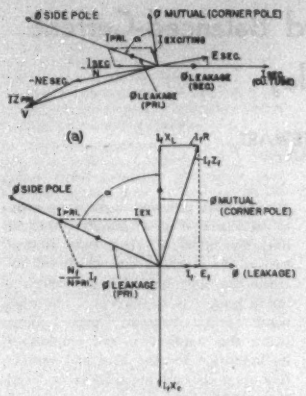

Figure 4. Vector diagrams showing flux relations

(*a*). Restraining circuit with copper tube
(*b*). The operation circuit with the floating circuit
Subscript *f* denotes floating circuit (secondary)

this condition, Steinmetz[7] has shown that the current in a series a-c circuit where $R^2 < 4L/C$ is equal to

$$i = \frac{E}{Z_0}\cos(\theta - \theta_0 - \gamma) - \frac{E}{Z_0}\epsilon^{-\frac{R}{2x}\theta}\left\{\cos(\theta_0+\gamma)\cos\frac{q}{2x}\theta + \left[\frac{2x_c}{q}\sin(\theta_0+\gamma) - \frac{R}{q}\cos(\theta_0+\gamma)\right]\sin\frac{q}{2x}\theta\right\} + \epsilon^{-\frac{R}{2x}\theta}\left\{i_0\cos\frac{q}{2x}\theta - \frac{2e_0+Ri_0}{q}\sin\frac{q}{2x}\theta\right\}$$

Where

E = maximum impressed voltage
R = resistance
x = inductive reactance
x_c = capacitive reactance
$Z_0 = \sqrt{R^2+(x-x_c)^2}$
$\theta = 2\pi ft$
t = time
f = frequency
$\gamma = \tan^{-1}\dfrac{x-x_c}{R}$
$q = \sqrt{4xx_c - R^2}$
θ_0, i_0, and e_0 = values at time equals zero

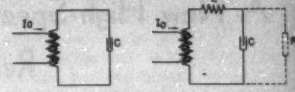

Figure 5. Diagram showing two forms of floating circuits

This equation consists of three parts:

1. The permanent term which is remaining after the transient is completed.
2. The transient term which is dependent on the circuit constant.
3. The third term depending on the initial electrical conditions. This last term disappears if the circuit is dead at the start.

A vector analysis (Figure 4B) for the floating circuit represents the flux relation during the steady-state operation. The angle α represents the phase displacement between the flux in coils C and D, and the torque is a function of the sine of this angle.

The oscillogram (Figure 6A) shows the current build-up in this circuit, and the magnitude for the first half cycle is only a fraction of its maximum steady-state condition. This leaves the operating circuit deficient in torque whereas the restraint build-up is immediate and has a restraining bias even though its current supply from the current transformer is affected by the residual magnetism.

Relay Characteristics

In reference to Figure 1 it will be noted that the operating coil of each unit is connected in series with the restraining coil of the other unit. Therefore, the fault current of one line which operates one of the units increases the restraint in the other, thus providing a selective operation. Figure 7 gives typical operating characteristics for both ground and phase relays with a 125 per cent slope. This slope has been used in the application of balanced-current relays to assure sufficient margin for the inequalities of current-transformer characteristics, line characteristics, and other factors af-

Figure 6. Oscillograms showing operation of relay during difference currents caused by residual magnetism. Two fault conditions are represented

(*A*). With an offset wave
(*B*). Symmetrical current wave

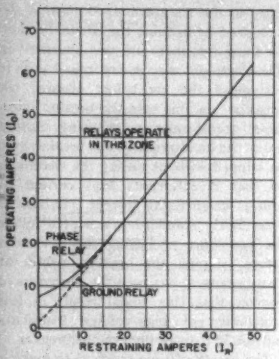

Figure 7. Operating characteristic of phase and ground balanced-current relays

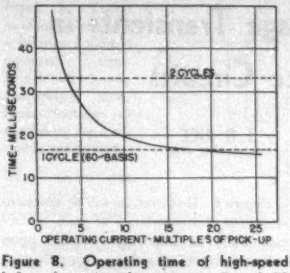

Figure 8. Operating time of high-speed balanced-current relay at zero, 5 and 20 amperes restraint

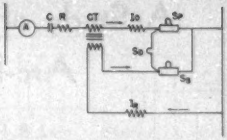

Figure 9. Test circuit used for checking relay operation and for oscillographic measurement of difference current

A—Ammeter
C—Synchronous switch
CT—Current transformer (ratio one to one)
I_O—Relay operating coil
I_R—Relay restraint coil
R—Reactor or load box
S_D—Oscillograph element to record difference current
S_P and S_D—Shunts with oscillograph elements, primary and secondary currents respectively

fecting the current balance. When these items are corrected or compensated, it should be satisfactory to use a relay functioning with a slope of 110 per cent.

The high-speed time characteristic is indicated in Figure 8 for this relay.

Tests

The testing program was composed of two parts:

1. A relay having all the characteristics presented in the forepart of this paper had to be developed and tested.

2. This same relay had to be subjected to operating conditions which equaled those found in the field. This part was conducted as a continuation of the work already covered on the current transformers and presented before the Institute.[1]

Typical oscillograms were taken using the test circuit of Figure 9, and these are reproduced in Figure 6 to show the instantaneous relation between the circuit characteristics as they affect the relay. The traces indicate current-transformer primary and secondary currents, the difference (or error) current, the operating-circuit build-up, the relay contacts, and the timing wave. With a 1/1 ratio current-transformer tests were made with the primary and secondary windings each connected in series with an oscillograph shunt and vibrator. Then the difference between the drop in the two shunts gives an instantaneous value which is a function of the difference current, and it is recorded by a third vibrator. Likewise, the instantaneous current magnitude of the floating circuit was recorded with the use of another oscillograph shunt and vibrator by a means which minimized its effect on the circuit's transient characteristic.

Conclusions

A balanced-current relay has been described which gives fast, sensitive protection comparable to that previously available yet faultless in operation when energized from current transformers previously saturated and containing residual magnetism. This has been accomplished at the expense of a slight delay of approximately one cycle which is easily tolerated. This has resulted from the application of the floating-circuit build-up to override the error current of the first cycle. Also, it can be expected that this feature will be useful in the design of other high-speed relays.

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A Study of Voltage Transients in Arc-Furnace Circuits

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IN the history of the operation of arc furnaces for melting steel there have been occasional evidences of overvoltage transients. These evidences have been chiefly electrical breakdown of equipment associated with arc furnaces which were not attributable to causes other than abnormally high voltage. In the last three years with the increased number of arc-furnace installations and the increased seriousness of interruptions to production, a considerable amount of attention has been focused on this problem. This paper presents the results of voltage surge measurements made on two furnace installations in an attempt to accumulate accurate data as to the magnitude of such overvoltages and the factors which influence them. Before entering into a discussion of voltage surges, however, it seems advisable to review the component electrical parts of an arc-furnace circuit and the procedure followed in its operation.

Furnace Circuits and Their Operation

Figure 1*a* is a simplified diagram showing the parts of a typical arc-furnace circuit, and Figure 1*b* is the corresponding schematic single-line diagram. In all but very large installations the separate reactor R is necessary because the inherent reactance of the circuit is not sufficient to produce over-all circuit stability so that an arc can be maintained. The vertical positions of the carbon electrodes in the furnace are individually and automatically controlled so as to maintain as nearly as possible constant current in each electrode. This regulating means is not shown in Figure 1. However, as will be apparent later, the characteristics of such control may have an important bearing upon voltage surges caused by instability of the arc, particularly during the melt-down period when the arc is most unstable. A companion paper[1] describes a new electrode control which it is believed has the advantage of increasing the stability of the arc.

After the furnace has been charged usually with steel scrap, the operator closes the circuit breaker which energizes the furnace transformer. The carbon electrodes are still clear of the charge, and therefore there is no load on the transformer. The operator now lowers the electrodes until they come in contact with the charge and an arc is initiated. The automatic control then takes over and attempts to regulate the electrodes so as to maintain constant current. However, in the initial part of the heat, before a considerable portion of the charge has been melted, it is not possible to maintain constant current, and the load fluctuates quite wildly between short circuit when the electrodes are in contact with metal and virtual open circuit when the arc may be completely extinguished or at least reduced to a very low current.

During this melt-down period the furnace transformer is operated in the upper range of the available secondary voltages with a correspondingly high value of reactance if a separate tapped reactor is used.

After the charge is completely or mostly melted, the operator changes taps on the transformer to obtain a lower secondary voltage and usually a lower reactance, so as to supply power to the furnace at a reduced rate. In doing this the operator must open the circuit breaker to de-energize the transformer. The melt is then continued for perhaps an hour to an hour and a half until such time as it becomes advisable to further reduce the rate of power input to the furnace. At this time the operator again changes taps on the transformer to obtain a still lower secondary voltage, and usually all the reactance other than that inherent in the transformer is cut out.

Each time that the operator changes taps on the transformer, it must be de-energized by opening the circuit breaker. In doing this there are two alternatives. The electrodes may be first raised so as to extinguish the arc before opening the breaker. In this case the breaker interrupts transformer magnetizing current only. As an alternative the breaker may be tripped without raising the electrodes so that it interrupts load current as well as magnetizing current. It has become fairly standard practice to follow the procedure of raising the electrodes before tripping the breaker, partly at least because it has been the concensus of opinion that this would result in less probability of high-voltage transients and also in reduced duty on the breaker.

The length of time required to make a complete heat of steel varies considerably depending upon the size of the furnace and the kind of steel being made. However, a typical figure may be taken as three hours. During this time according to the procedure outlined, the breaker will be closed and opened three times in order to start the heat and change taps. On the average there will be perhaps two or three additional switching operations for various reasons, such as slagging off, lengthening electrodes, and so forth. A total of six switch closings and six trippings per heat is perhaps a reasonable figure. Many installations are at present operating 24 hours per day, and with an average length of heat of three hours, this would mean approximately 40 to 50 switch operations per day. Some instal-

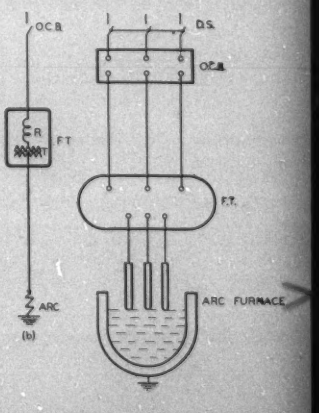

Figure 1. Typical arc-furnace circuit

DS—Disconnect switch
OCB—Oil circuit breaker
FT—Furnace transformer with self-contained reactor

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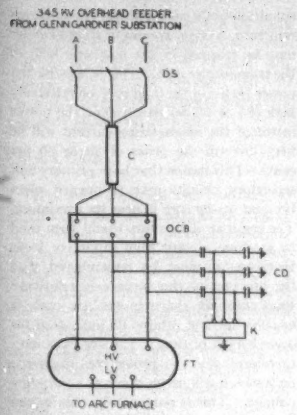

Figure 2. Furnace circuit at location *A*

DS—Disconnect switch
C—34.5-kv three-conductor type *H* underground cable 650 feet long
OCB—Oil circuit breaker
FT—Furnace transformer with self-contained reactor
CD—Capacitance potential divider
K—Klydonograph

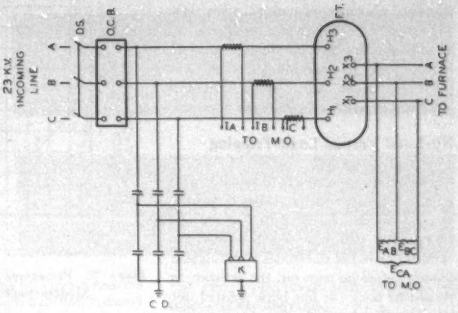

Figure 3. Circuit used for making tests at location *B* without potential transformers in the circuit. Secondary transformer voltages recorded by the magnetic oscillograph

DS—Disconnect switch
OCB—Oil circuit breaker
FT—Furnace transformer with self-contained reactor
CD—Capacitance potential divider
K—Klydonograph
MO—Magnetic oscillograph

lations have as many as 100 switch operations per day.

Possible Causes of Voltage Surges

Following the preceding discussion of furnace operation we may list the following possible causes of voltage transients in arc-furnace circuits:

(*a*). Instability of the arc.

(*b*). Raising or lowering the electrodes to interrupt or start the arc.

(*c*). Switching.

The role played by intermittent arcing in the production of high-voltage transients on transmission systems is well known. It seems logical therefore to expect that a similar phenomenon might be found in circuits in which the load itself is an arc. If this is true, voltage surges should be particularly noticeable during the melt-down period when the arc is most unstable. Furthermore, it is the authors' opinion that the systems supplying most arc furnaces are so large that they offer very low impedance to surges originating on the low-voltage side of the transformer and therefore tend to suppress the transmission of such transients to the high-voltage side of the transformer. This being the case, voltage transients caused by arc instability should be observable, principally, on the secondary side of the transformer. At one of the two installations tested, special steps which are described later were taken to detect the presence of overvoltages on the high-voltage side of the transformer during furnace operation, and it was found definitely that no appreciable overvoltages occurred. On the other installation, no special steps were taken to detect surges on the high-voltage side during furnace operation, but an examination of Klydonograph film records of regular heats indicates, although not conclusively, that overvoltages were not obtained on the primary side except when switching occurred. No tests were made on the low-voltage side of the furnace transformer.

Since it is common practice to raise the electrodes before tripping the breaker and to lower the electrodes after the breaker is closed, it is possible that the interruption and initiation of the arc by this means might result in voltage surges. At one of the installations tested by a procedure described later, it was definitely determined that overvoltages were not obtained on the high-voltage side of the transformer when the electrodes were raised or lowered to terminate or strike the arc in the furnace. This test was not made at the other installation.

It is well known that the operation of switches in electrical circuits may cause voltage surges and that the magnitude of these surges depends upon the characteristics of the circuit and of the switch. Furnace circuits are not essentially different from other power circuits, except for the fact that the load has the peculiar characteristics of an arc. It might be expected, therefore, if there is any difference between the character of switching surges obtained on furnace circuits from those obtained on other power circuits that it would be observed when switching under load. It is advisable, therefore, to consider separately the conditions which exist when switching under load and when switching no-load, and also when closing and opening the circuit.

Although closing the circuit breaker under load is probably not practical for

Table I. Comparison of Two Installations Tested

	Location A	Location B
Primary voltage	34.5 kv	24 kilovolts
Frequency	60 cycles	60 cycles
Transformer (secondary delta connected)	3,000 kva, 3 phase	3,000 kva, 3 phase
Delta to wye primary switch	Internal	Internal
Secondary voltage range with		
Primary winding in delta	220–140 volts	235–160 volts
Primary winding in wye	127–81 volts	136–93 volts
Reactor	Internal, 21 per cent	Internal, 20 per cent
Oil-circuit-breaker current rating	600 amperes	600 amperes
Oil-circuit-breaker interrupting rating	500,000 kva	500,000 kva
Oil-circuit-breaker insulation	46 kv	34.5 kv
System grounding	Petersen coil—26 miles away	Solid—4 miles away
Miles of connected high-voltage line	350	4
Underground cable	650 feet, type *H*, 3*C*, 34.5 kv	None
Lightning arresters	Oxide film	Porous block—25 kv
Distance from lightning arrester to furnace	700 feet (source side of cable)	50 feet (end of line)
Instruments used in tests	Klydonograph	Klydonograph Cathode-ray oscillograph Magnetic oscillograph
Circuit diagram showing instruments	Figure 2	Figures 3 and 4
Secondary grounding	Lamps	Lamps

standard operating procedure, a few tests were made as a matter of interest and are reported under "Test Results." As might be expected, no overvoltages resulted at the transformer high-voltage terminals although current inrushes were obtained.

No-Load Versus Load Tripping

There has been much discussion with reference to the relative merits of switching out under load or with load on the transformer. In other words, should the operator raise the electrodes to extinguish the arc before he trips out the breaker, or should he not? It has been pointed out by some that breaking transformer magnetizing current may cause a voltage surge because of the inductive kick produced by the sudden collapse of the stored magnetic field in the transformer core. However, it must be remembered that the transformer core is a closed magnetic circuit and therefore will retain permanently a residual magnetization which is usually in the order of 60 per cent of the maximum induction. Furthermore, if the current is interrupted in the breaker at normal current zero, without appreciable distortion of the current wave, there will be no inductive kick at all because both flux and current will decrease along their normal paths to their steady-state value corresponding to current zero. In most modern breakers this is usually very close to what actually happens, because such breakers do not greatly tend to force current zero. Although breaking transformer exciting current can undoubtedly produce inductive kicks of two to three times normal (some of the film records obtained show such inductive kicks) it seems unlikely that overvoltages caused by breaking magnetizing current should be a source of serious concern.

Those who have advocated no-load tripping as preferable to tripping under load point out that interrupting load current may be dangerous because if the arcs in the circuit breaker and furnace are simultaneously extinguished at load-current zero, a large amount of stored energy may be trapped in the magnetic field of the transformer core. This is because the power factor of the load may be relatively high (85 or 90 per cent) while the power factor of the magnetizing current will be very low (in the order of 20 or 30 per cent). This means that both primary and secondary circuits may be opened when the flux in the core is near its maximum. The collapse of this flux would then tend to produce a very high inductive kick. However, it must be remembered that the arc gap in the furnace is relatively short and the space in the arc path is usually hot and retains its ionization for some length of time. The arc path may therefore offer a protective discharge path which will break down at a very low voltage. This is particularly true in the latter parts of the heat. During the melt-down period, however, when the arc is still comparatively long and when the arc space cools rapidly upon extinction of the arc, the trapping of magnetic flux in the core as has been described is believed to be a possible cause of overvoltages which may produce insulation failures. In considering this it should be remembered that the voltage required to break down the arc in the furnace will be multiplied on the high-voltage side of the transformer by the turn ratio. In the tests a number of surges of several times normal (up to approximately four times normal) were obtained because of tripping under load, chiefly in the early parts of heats. On the other hand, quite a few load trippings made after the charge was melted down produced no appreciable surges.

Summing up, it is believed that tripping

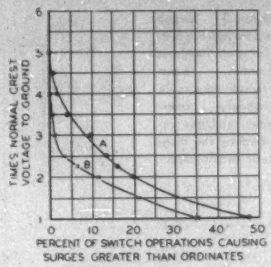

Figure 5. Percentage distribution curves of Klydonograph surge records

Curve *A*—Location *A*
Curve *B*—Location *B*

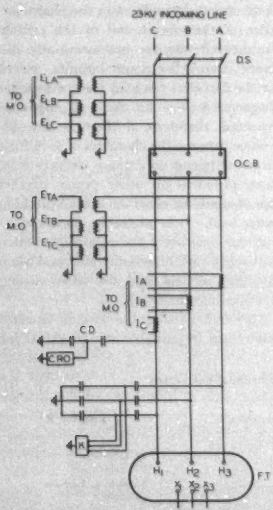

Figure 4. Circuit used in making tests at location *B* in which potential transformers were used. Primary transformer voltages recorded by the magnetic oscillograph

DS—Disconnect switch
OCB—Oil circuit breaker
FT—Furnace transformer with self-contained reactor
CD—Capacitance potential divider
K—Klydonograph
MO—Magnetic oscillograph
CRO—Cathode-ray oscillograph

Table II. Summary of Test Results

	Location A	Location B
Approximate total number of switch operations (close or trip)	1,400	1,000
Approximate total number of surges recorded on Klydonograph	650	200
Approximate number of heats recorded on Klydonograph	70	50
Total number of surges recorded on cathode-ray oscillograph	None	110
Total number of surges recorded on magnetic oscillograph	None	150
Maximum switching surge—times normal	5.2	3.8
Surges unidirectional or oscillatory	Unidirectional	Both
Polarity of Klydonograph surge figures	Positive and negative equal	Mostly positive
Surges on primary circuit caused by load	No	Probably not
Surges caused by tripping or closing breaker	Closing chiefly	Both equally
Surges caused by raising or lowering electrodes	No	No test
Effect on switching surges of		
Transformer tap position	Not important	Not important
Supply-system grounding	See Figure 6	No test
Underground cable ahead of breaker	See Figure 6	No cable
Natural frequencies of switching transients		
No-load tripping	No test	6,500 to 10,000
Load tripping	No test	5,000
No-load closing	No test	6,000 to 9,500
Load closing	No test	6,200
Percentage distribution curve of switching surges	Figure 5	Figure 5

under load in the latter parts of the heat with a short hot arc may cause lower overvoltages than tripping at no-load, but tripping under load in the early parts of the heat before melting down is completed definitely should be avoided.

Circuit Data

Tests were made on two installations identified in this discussion as location *A* and location *B*. The pertinent information on the furnace circuits and the power systems supplying them is presented in tabular form in Table I. It will be noticed that the chief difference between location *A* and location *B* lies in the supply system. The furnace circuits including the transformers and circuit breakers are similar, except for the primary voltage rating.

Important differences in the supply system are:

1. The system at location *A* is 34,500 volts, while at location *B* it is 24,000 volts.

2. Location *A* has 350 miles of connected high-voltage line, while location *B* has only approximately four miles. The 350 miles of line supplying location *A* consist of a 34.5-kv loop. A spur line four miles long supplies the furnace, and there is no other load on this line. The 24-kv line supplying location *B* originates at a step-down substation four miles away. There is one other furnace on this same line, approximately 50 feet beyond the one tested, where the line terminates.

3. The 34.5-kv loop supplying location *A* is normally grounded through a Petersen coil at only one point, about 26 miles from the furnace, while the line supplying location *B* is solidly grounded at a substation four miles away.

4. Location *A* is served by a 650-foot length of three-conductor underground cable just ahead of the oil circuit breaker (see Figure 2), while there is no underground cable at all in the circuit at location *B*.

5. The only surge protection on location *A* is a bank of obsolete oxide film arresters located on the source side of the underground cable, approximately 700 feet from the furnace, while location *B* is protected with modern lightning arresters at the end of the line, approximately 50 feet beyond the test location.

At both installations the furnace shell, transformer tank, and electrode control have a common ground.

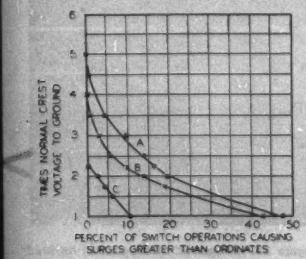

Figure 6. Comparison of Klydonograph tests at location *A*

Curve *A*—Normal condition with system grounded through Petersen coil

Curve *B*—System solidly grounded at three points

Curve C—Underground cable on source side of circuit breaker replaced by overhead line

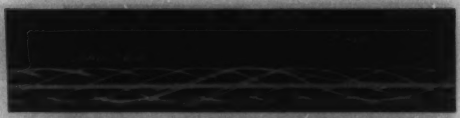

Figure 7. Cathode-ray oscillogram of tripping circuit breaker under load —moving film

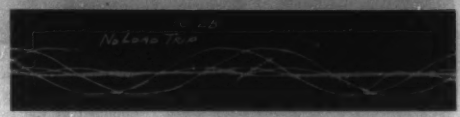

Figure 8. Cathode-ray oscillogram of no-load tripping operation — moving film

Test Results

The circuit used in making tests at location *A* is shown in Figure 2. The Klydonograph only was used on this installation.

Some of the data obtained at location *B* were made with the Klydonograph and magnetic oscillograph only. The circuit is shown in Figure 3. Other tests were made at location *B* in which the cathode-ray oscillograph was used on one phase as well as the Klydonograph and magnetic oscillograph. The location of the test apparatus in the circuit is shown in Figure 4. Still other tests were made with a circuit similar to Figure 4 except that the potential transformers on the line side of the circuit breaker were connected across the three poles of the breaker to record breaker voltage on the magnetic oscillograph.

A total of approximately 2400 switch operations was recorded on the Klydonograph, resulting in approximately 850 surge figures of such magnitude as to be measurable. In addition a total of approximately 120 normal heats were recorded on the Klydonograph. At location *B* 110 switch operations were recorded on cathode-ray oscillograms, and 150 switch operations were recorded on magnetic oscillograms.

The results are summarized in comparative form in Table II.

In analyzing the results the Klydonograph data only were used for quantitative results such as presented in the percentage distribution curves of Figures 5 and 6. It was not possible to obtain sufficient oscillographic data for such a statistical analysis. However, in general, the magnitudes recorded on oscillograms gave a reasonable check with those from the Klydonograph. The oscillograms were used chiefly to obtain information on the nature of the surge wave shapes, such as natural frequencies, restriking, and so forth. The only reliable information about wave shape yielded by Klydonograms is polarity, and even this must sometimes be questioned, as explained later.

An attempt was made to plan the test procedure so that answers might be obtained to as many as possible of the following questions:

1. *What is the polarity of the Klydonograph surge figures?* (The character of positive and negative surges is quite different, and the two are easily distinguished.[4]) The results obtained in connection with this question are taken up in detail later.

2. *Are overvoltages caused by the furnace load?* At location *A* a number of regular heats were attended, and the Klydonograph film was moved by hand after each switch operation and after each time that the electrodes were raised or lowered. By this means it was determined that the only overvoltages obtained occurred on switching. No such tests were made at location *B*, but an examination of the Klydonograph records leads to the tentative conclusion that here also surges were caused only by switching.

3. *Are overvoltages caused by raising and lowering the electrodes to interrupt or start the arc?* By the same procedure of moving

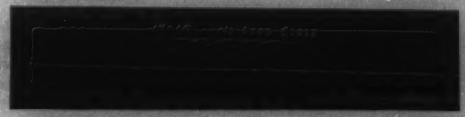

Figure 9. Cathode-ray oscillogram of no-load closing operation — moving film

Figure 10. Cathode-ray oscillograms of no-load closing operation using single sweep of the oscillograph

(*a*). 60-cycle sweep
(*b*). 300-cycle sweep
(*c*). 900-cycle sweep

the film as previously described, it was also ascertained at location *A* that lowering and raising the electrodes did not cause voltage surges. (Again no tests were made at location *B*.) This result is not surprising since electrode motion is very slow and interruption probably occurs at normal current zero without any appreciable disturbance.

4. *Are overvoltages caused by closing the breaker on load?* Closing the breaker on load was done at location *B* only. No overvoltages were observed from this operation, although as would be expected, current surges were obtained.

5. *Are overvoltages caused by tripping the breaker underload?* Surges of several times normal were obtained on both installations by tripping underload during the early part of a heat. However as stated previously, it was found that load tripping after meltdown when the arc is short and hot did not produce appreciable overvoltages.

6. *In no-load switching are the severest surges caused by closing or by tripping?* The results are discussed under "No-Load Switching Tests."

7. *What is the effect on no-load switching surges of:*

(*a*). *Transformer tap position?* The tests on both installations showed that the transformer tap position did not have any important effect on the magnitude of switching surges.

(*b*). *Supply-system grounding?* This test was made at location *A* only, and the results are shown in Figure 6 and are discussed in detail later.

(*c*). *The effect of the underground cable at location A?* Results of this test are shown in Figure 6 and are discussed in detail later.

8. *What are the natural frequencies of the switching transients?* The natural frequencies obtained from the cathode-ray oscillograms at location *B* are shown in Table II, and typical oscillograms are shown in Figures 7 to 14, inclusive.

No-Load Switching Tests

Since the voltage surges were found to be caused mostly by switching, and since the usual procedure is to switch no-load, the bulk of the testing was devoted to accumulating data on no-load switching. An analysis of these data reveals some striking differences between the results obtained at the two different locations, and these differences are believed to be explained by the unusual combination of circuit characteristics at location *A*.

It is believed that location *A* is rather unique and is of particular interest for several reasons.

1. It is one of a very few 34,500-volt furnace-transformer installations in this country.

2. The presence of the underground cable ahead of the circuit breaker, together with the great length of connected high-voltage line and the Petersen-coil ground, is somewhat unusual.

It will be noticed in Table II that the maximum surge obtained on location *A* was considerably greater than location *B*. The difference is even more evident in Figure 5 in which curve *A* represents switching surges at location *A*, and curve *B* represents those at location *B*. The difference between typical Klydonograph films from location *A* and location *B* is striking, because of the much greater size and frequency of surge figures on films obtained at location *A*. Figure 15 is a sample Klydonogram from location *A*. Part of the difference between the severity of surges at locations *A* and *B* may possibly be explained by the better lightning protection at location *B*. (See Table I.) However, in both cases the lightning arresters are on the other side of the circuit breaker from the surge-measuring instruments. It is believed that the lightning arresters at location *B* were not operative to any great extent in reducing the maximum value of the surges because there was no tendency of the percentage distribution curve to flatten off near the upper voltage limit. (See Figure 5.)

Several other differences between the results obtained at locations *A* and *B* are of interest.

Polarity

At location *A* all of the Klydonograph figures for switching were unidirectional in nature and approximately equally distributed between positive and negative. At location *B* nearly all of the figures appeared to be positive. The explanation for this difference is believed to be that surges at location *A* were truly unidirectional, while those at location *B* as evidenced by the supporting oscillographic films, resulted in both positive and negative voltages for each surge in nearly every case. This being the case, the positive figures would tend to cover up completely the negative figures since they are more than twice as large. Also it happens that the 60-cycle normal voltage line which appears in records where the film is clock-driven is sufficiently wide to hide completely all but the very highest voltage negative figures. As it happened at location *A*, a slight unbalance in the line-to-ground voltages caused the 60-cycle normal-voltage line to appear on only one phase, permitting all negative surge figures to be seen easily on the other two phases. Another interesting point is that in most cases at location *A* the surges appeared to be of the same polarity and the same order of magnitude on all three phases indicating that the entire winding rose above ground, while this was not at all the case at location *B*.

Comparison of Closing and Tripping Surges

At location *A* it was surprising to find that nearly all appreciable no-load switching surges were obtained when the breaker was closed, only a very few surges of minor magnitude being obtained for

Figure 11. Magnetic oscillogram of no-load tripping recording line to neutral voltages on transformer side and supply side of the breaker—Figure 4

I_A, I_B, I_C—Line currents
E_{TA}, E_{TB}, E_{TC}—Transformer voltage of phases *A*, *B*, and *C*
E_{LA}, E_{LB}, E_{LC}—Voltages on the supply side of the breaker of phases *A*, *B*, and *C*

Figure 12. Magnetic oscillogram of no-load tripping operation recording transformer voltages and breaker voltages

I_A, I_B, I_C—Line currents

E_{TA}, E_{TB}, E_{TC}—Transformer voltages of phases *A*, *B*, and *C*

E_{BA}, E_{BB}, E_{BC}—Voltages across breaker contacts in phases *A*, *B*, and *C*

no-load tripping. At location *B* on the other hand, switching surges were approximately equally distributed between closing and tripping both in number and magnitude, with the balance slightly in favor of tripping.

The closings were distinguished from the trippings by moving the Klydonograph film by hand after each closing or tripping. This resulted in a normal 60-cycle line on the film after each closing and a blank space after each tripping. In Figure 15 all of the important surge figures occur at the start of the 60-cycle line, showing that they were produced by closing the breaker.

Effect of Supply-System Grounding

Tests were made to determine the effect of system grounding at location *A*, and the results are shown in Figure 6 by a comparison of curves *A* and *B*. There seems to be an appreciable reduction in the magnitude of switching surges with the system solidly grounded as represented by curve *B*. For this test the system was solidly grounded at three points, the nearest point being at the junction of the spur line and 34.5-kv loop four miles away.

Effect of Underground Cable at Location A

Fortunately it was also possible to make tests with the underground cable out of service and replaced by a temporary overhead line. The results are shown in curve *C* of Figure 6, and the great reduction in the magnitude of switching surges is evident. The maximum surge was reduced from five to approximately two and one half times normal.

It is believed that the great difference between results obtained at locations *A* and *B* are due chiefly to three factors, namely:

1. Better surge protection at location *B*.
2. Presence of the capacitance of the underground cable and great length of connected line at location *A*.
3. The difference in grounding of the two supply systems.

Of these, based on the result of the tests, it is believed that the presence of the cable is most important.

The great effect of the cable might be explained by the cumulative effect which occurs in capacitive circuits when restriking occurs and which is absent in inductive circuits. The effect of the system grounding may be partly because of more rapid draining of charge from the cable with the solidly grounded condition.

Typical Oscillograms

Figures 7 to 9 are cathode-ray oscillograms made with a moving film, and Figure 10 is a cathode-ray oscillogram in which the single-sweep arrangement on the oscillograph was used. Figures 11 to 14 are magnetic oscillograms.

Figure 13. Magnetic oscillogram of tripping underload recording transformer voltages and line to neutral voltages on the supply side of the breaker—Figure 4

I_A, I_B, I_C—Line currents

E_{TA}, E_{TB}, E_{TC}—Transformer voltage of phases *A*, *B*, and *C*

E_{LA}, E_{LB}, E_{LC}—Voltages on the supply side of the breaker of phases *A*, *B*, and *C*

Figure 14. Magnetic oscillogram of tripping under load recording transformer voltages and breaker voltages

I_A, I_B, I_C—Line currents

E_{TA}, E_{TB}, E_{TC}—Transformer voltages of phases *A*, *B*, and *C*

E_{BA}, E_{BB}, E_{BC}—Voltages across breaker contacts in phases *A*, *B*, and *C*

Figure 7 is a record of a load tripping operation in which restriking occurred twice, and the final interruption resulted in an inductive kick to approximately twice normal.

Figure 8 is a typical no-load tripping record. It will be observed that arcing lasted for approximately one cycle, and this is typical as evidenced also by the magnetic oscillograms. The large lower frequency oscillations are restriking at successive current zeros. It was not possible to resolve the very high-frequency oscillations between these points on any of the film records obtained.

Figure 9 is a typical no-load closing operation in which the shape of the long-time transient is attributed to the fact that the circuit was made at different times on two phases.

Figure 10*a* is a no-load closing in which a 300-cycle sweep was used. A similar closing is shown in 10*b* at a 60-cycle sweep, and at 10*c* in a 900-cycle sweep. The frequency is approximately 6,500 cycles. In 10*b* the effect of making at different instants of time on different poles of the breaker is clearly shown. The maximum voltage obtained, however, is only approximately normal crest voltage.

Natural frequency oscillations obtained on no-load tripping are clearly seen in Figures 11 and 12, and the absence of these oscillations is striking in the load trip magnetic oscillograms in Figures 13

and 14. However, it will be observed that in the load trip records, arcing is extended over nearly two cycles while the arcing period is approximately one cycle in the case of no-load tripping.

Most of the film records obtained for both tripping and closing show three or more restrikes and making or breaking of the circuit at different times on the different phases.

Conclusions

1. Voltage surges occurring on the high-voltage terminals of arc-furnace transformers are caused largely by switching.

2. Tripping out under load can cause high overvoltages chiefly in the early parts of the heat when the arc space is long and cools rapidly. Load tripping, during the later parts of the heat may result in lower voltage transients than no-load tripping but in extended arcing. As a general practice it is better to raise the electrodes before tripping the breaker.

3. Since no-load switching is general practice, the problem of switching surges on furnace circuits is not essentially different from that of other power circuits, except that switching is more frequent and the circuit constants may be quite different.

4. Because the problem of overvoltages, at least on the high-voltage side, reduces to one of switching surges, the characteristics of the supply system, as well as of the furnace circuit and the switch, will determine the magnitude of voltage surges obtained. In particular the grounding of the power system is important.

5. The presence of a length of underground cable on the source side of the circuit breaker used for switching may be the cause of excessive overvoltages.

6. It is realized that the data presented here are far from complete or conclusive, and it is believed that further study of the problem of voltage transients in arc furnaces is warranted, particularly with a view to obtaining measurements on the low-voltage side of the transformer.

Figure 15. Typical section of Klydonograph film obtained in no-load switching tests at location *A*

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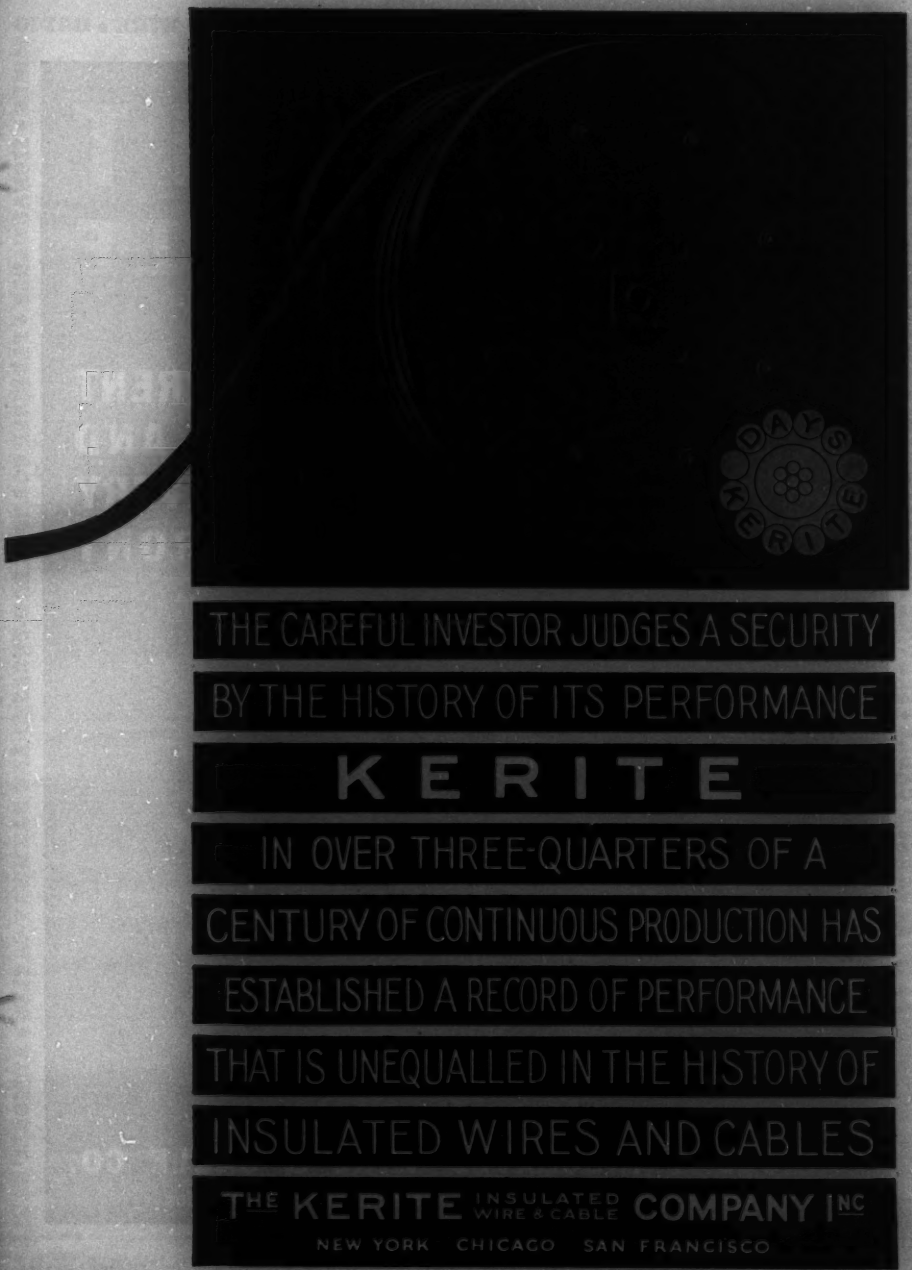
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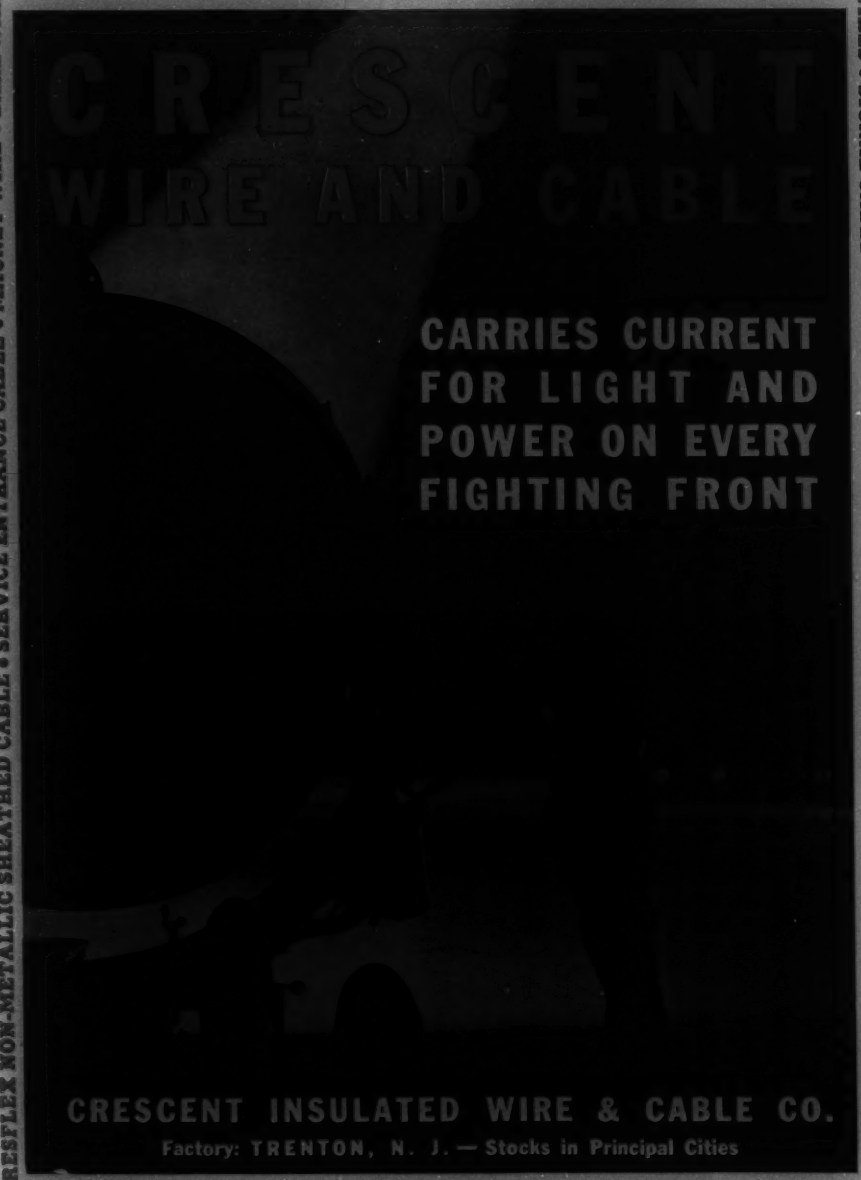

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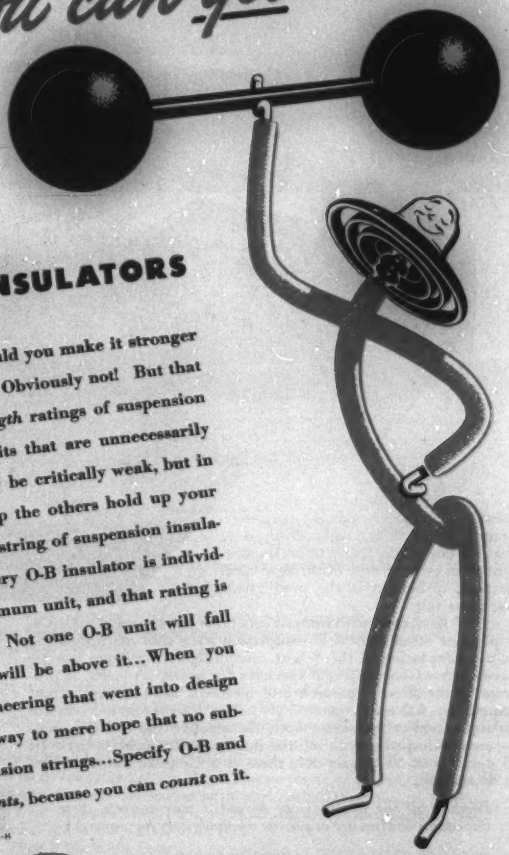

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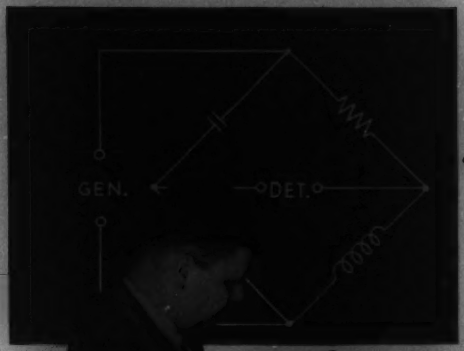

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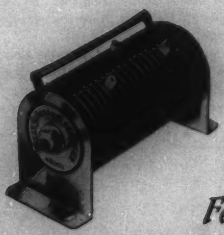

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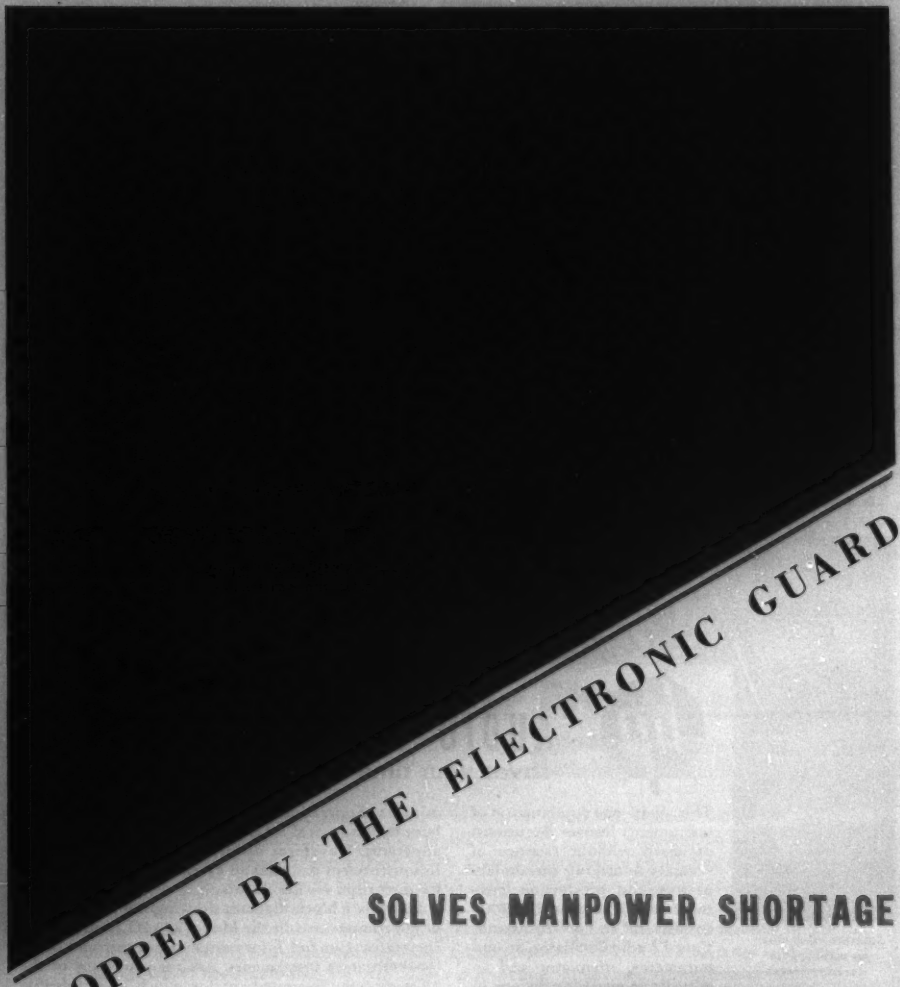

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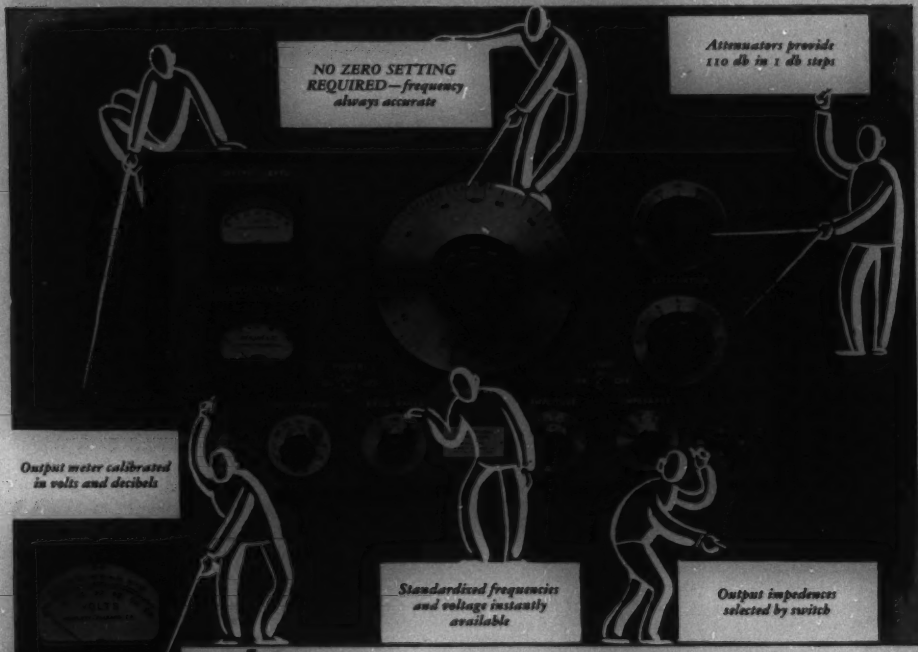
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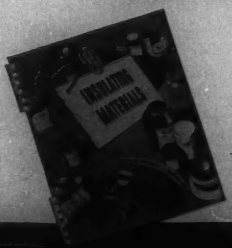

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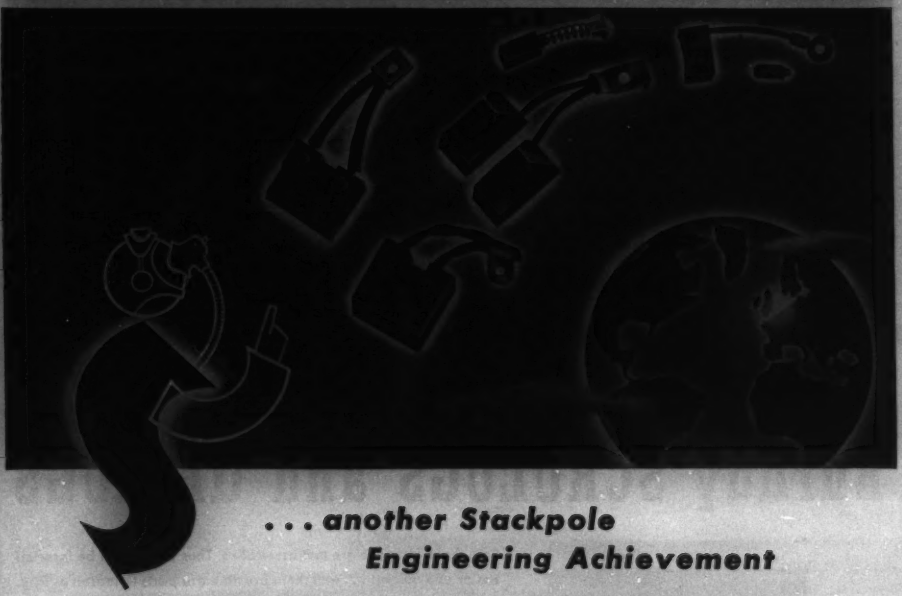

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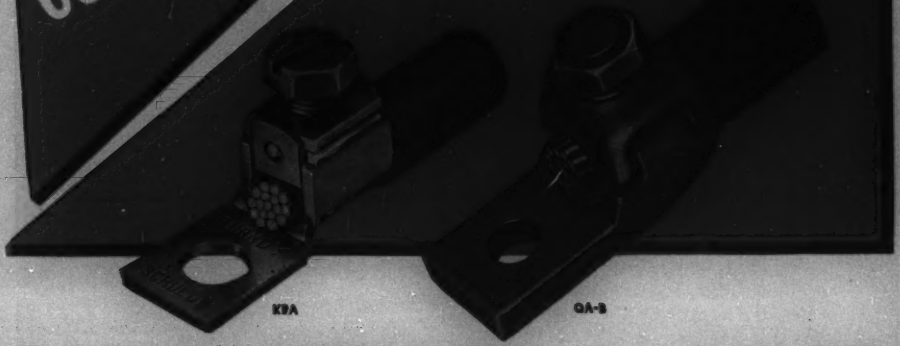

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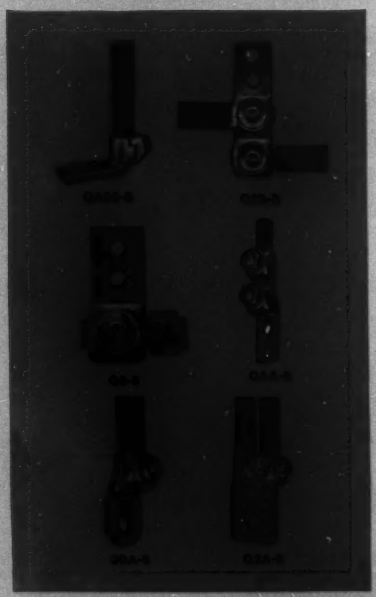

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The Qiklug also provides extreme compactness, and is equipped with an oversize stud to eliminate all danger of stripping or distortion when tightening. And only 11 sizes of the standard Qiklug are necessary for cables ranging from #3 to 2000 mcm. Also supplied in variations to meet all connector needs.

Catalog giving complete information on these and other time-saving, cost-cutting Burndy connectors gladly sent on request.

Engineering for Electronics

Burndy

BURNDY ENGINEERING CO., INC.
107 Eastern Boulevard • New York 54, N. Y.

3 Plants... 2 Flags... ONE PURPOSE

To beat the band of Axis bandits, three Solar factories are now operating "round the clock". The men and women of Eastern Plants 1 and 2 were told "Well Done" by the Army and Navy; they proudly wear the Army-Navy "E".

The Midwestern Plant has just started production; the men and women of this modern air-conditioned factory are ready to help you speed the day of Victory.

If your capacitor or filter problem is made ours, you can be certain of "Quality Above All".

Solar Manufacturing Corporation, General Offices: Bayonne, New Jersey.

Solar SOLAR — CAPACITORS —

CAPACITORS and RADIO NOISE SUPPRESSION FILTERS

Here's What They're Doing with

Vinylite Plastics

LIGHT WEIGHT AND STRENGTH are important characteristics of records made from VINYLITE Rigid Sheet for sound recording and transcribing purposes. Although wafer-thin, these records are virtually unbreakable. Their exceptional dimensional stability provides high fidelity in transcribing, and prevents warping and distorting under normal changes in temperature and humidity.

DIMENSIONAL STABILITY and unfailing accuracy are assured for calculating instruments used in aircraft navigation when VINYLITE Rigid Sheets are used. One manufacturer claims calibrations can be printed to even closer tolerances on these materials than on metal sheets. Moreover, the plastic sheets require no finishing as do metal sheets.

THERE ARE three major reasons why VINYLITE Plastics are outstanding among thermoplastic materials now available to industry . . . their unique combinations of properties, their varied forms that are suited to many fabricating techniques, and the vast opportunities they present for improving the design and performance of a wide range of products.

In VINYLITE Plastics you will find materials that are basically odorless, tasteless, non-toxic, non-flammable, and highly resistant to moisture, oils, and chemicals . . . types that can be rigid or flexible . . . transparent, translucent, or opaque . . . colorful or colorless . . . as desired.

These valuable properties are obtainable for a diversity of products, since VINYLITE Plastics can be either injection or compression molded, extruded into tubes or rods, or used as the basis for coatings on cloth, metal, paper, or concrete. They can be compounded into adhesives. Rigid sheets of VINYLITE Plastics can be formed into a wide variety of flat or three-dimensional shapes.

The developments described on these pages are typical of hundreds of applications of VINYLITE Plastics that are helping to meet today's critical needs better, faster, and frequently at lower cost. A further indication of what *you* can gain with these materials can be obtained by writing for Booklet 1 VE, "Vinylite Resins—Their Forms, Properties and Uses."

Plastics Division
CARBIDE AND CARBON CHEMICALS CORPORATION
Unit of Union Carbide and Carbon Corporation
UCC
30 EAST 42ND STREET, NEW YORK, N. Y.

ACID AND ALKALI RESISTANCE of VINYLITE Elastic Plastics are employed to excellent advantage for flexible hose used in chemical service. Aging and constant exposure to light will not cause these plastics to deteriorate. Transparent extruded tubing of this type, serving as abrasion-resistant conduit for electrical wiring, simplifies inspection of vital light and power lines.

FLAME AND ABRASION RESISTANCE are outstanding qualities of wire and cable insulation made from VINYLITE Elastic Plastics. Because it is non-oxidizing, this improved insulation is more highly resistant to aging than rubber compounds formerly used. Primary insulation is extruded directly around the wire. Jacketing for outer protection is provided in the form of extruded tubing or tapes made from VINYLITE Flexible Sheeting. A wide color range facilitates color coding.

UNUSUAL CORROSION RESISTANCE for the interiors of emergency drinking water containers is provided by linings based on VINYLITE Resins. These coatings are applied by the American Can Company and are similar to those used by that company for beer cans. These impervious linings prevent interaction of can and contents. They are baked to a glasslike finish, but are highly resistant to impact shocks even at extremely cold temperatures. Because of these characteristics, the sterile water is protected against contamination during prolonged storage.

SIMPLIFIED PRODUCTION

—The control panel illustrated is typical of the production economies made possible by VINYLITE Plastics. In this instance, the panel is formed, complete in every detail, by a simple molding operation. The technique employed is an adaptation of the plastic printing plate development that makes it possible to conserve substantial quantities of precious metals, and to save even more precious man-hours on the production line.

There are two fundamental steps. First, a matrix of BAKELITE Phenolic Material is made from an etched copper pattern. Second, the phenolic matrix or mold is used to form any number of duplicates from a special VINYLITE Plastic molding compound. Slots, holes, and markings, including intaglio lettering, are incorporated in the panel in this molding operation. A simple pigment "wipe" accentuates the markings and lettering. Then, the flat panel is curved to final shape under heat and pressure on a wooden mandrel. This simple technique eliminates many operations that were formerly necessary with metal plates, such as drilling, engraving, slotting, anodizing, and polishing.

(Panels Molded by Thos. Moss & Co., Inc.)

Vinylite
TRADE MARK
ELASTIC PLASTICS • RIGID PLASTICS
RESINS FOR ADHESIVES
RESINS FOR SURFACE COATINGS
*The words "Vinylite" and "Vinylseal" are registered trade-marks of Carbide and Carbon Chemicals Corporation.

WATERPROOFNESS AND TOUGHNESS

for the coverings used on Navy binoculars, which formerly demanded highly cured rubber, are now provided by an embossed sheeting of VINYLITE Elastic Plastics. This plastic covering requires no curing or vulcanizing . . . withstands the corrosive action of salty spray, and prevents penetration of water vapor which would fog the lenses.

"VINYLITE" ELASTIC PLASTICS

Rubber-like materials produced in a variety of forms, ranging from soft to semi-rigid. Possess great toughness and good resistance to continuous flexing, and to severe wear and abrasion. Tensile strength greater than that of most rubber compounds. Have excellent electrical insulating properties, and do not oxidize. Can be made non-flammable and highly resistant to water, oils, and corrosive chemicals by correct choice of plasticizer.

Available in a wide range of translucent or opaque colors, or in colorless types. Supplied as sheeting, compounds, for calendering onto cloth, molding and extrusion compounds, or as powdered resins for industries that have compounding equipment, such as the rubber industry. No curing or vulcanizing is required.

"VINYLITE" RIGID PLASTICS

Produced from unplasticized vinyl resins, these various forms of plastics possess a combination of properties not found in other thermoplastic materials. Having extremely low water absorption, they remain dimensionally stable under widely varying atmospheric conditions. Outstanding in resistance to alcohols, oils, and corrosive chemicals. Have high impact and tensile strengths. Odorless, tasteless, and non-toxic. Do not support combustion.

Available in natural transparent, as well as transparent, translucent, and opaque colors. Supplied as rigid sheets, or as molding and extrusion compounds. Rigid sheet can be fabricated by forming, drawing, blowing, spinning, or swaging, and can be punched, sheared, sawed, or machined with metalworking tools. Molding compounds adaptable to both compression- and injection-molding processes.

"VINYLITE" RESINS FOR SURFACE COATINGS

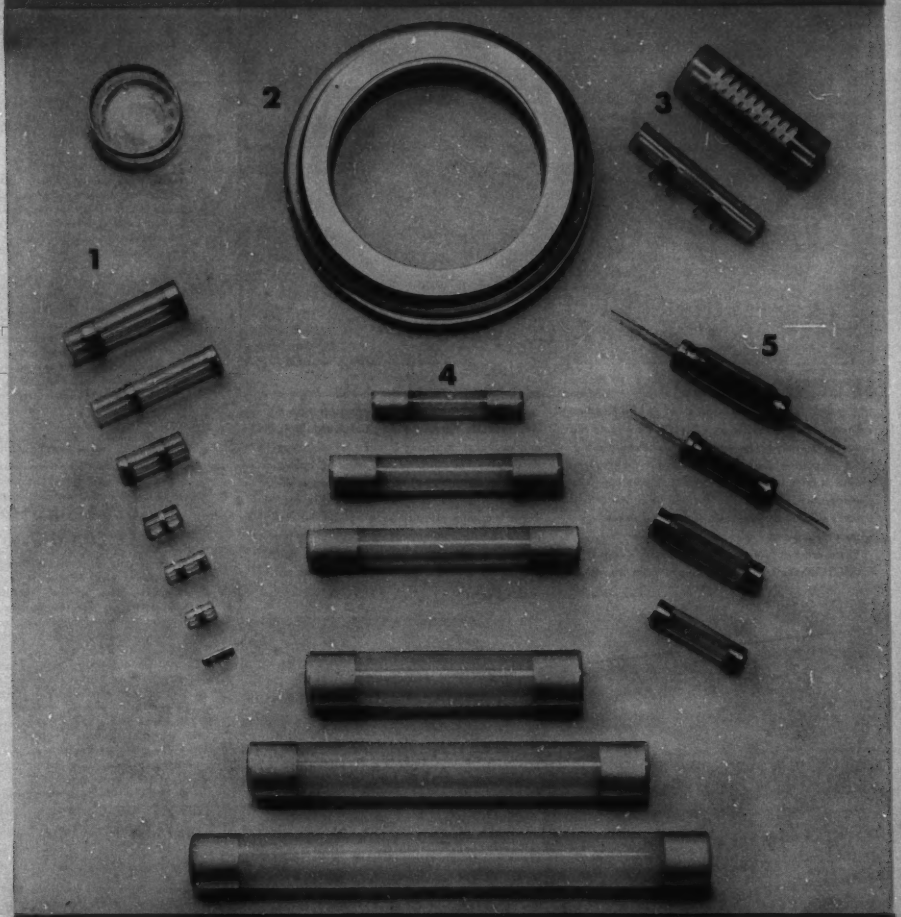
When correctly formulated and applied, these resins yield finishes of unusual toughness, gloss, adhesion, and chemical resistance. Can be applied by spraying, knife-coating, or dipping to a wide variety of surfaces, such as metal, cloth, paper, and concrete. Prepared by dissolving resins in organic solvents, these finishes can be modified with different pigments, dyes, and plasticizers. The resins are generally not employed with other film-forming bases, thus coatings formulated from them exhibit the desirable features of VINYLITE Resins alone. Drying is solely by solvent evaporation. Finishes can be either air-drying or baking types.

"VINYLITE" RESINS FOR ADHESIVES

Unusual toughness, resiliency, and impact resistance are characteristic of adhesives made from these resins. They are widely used as bonding agents for such materials as cellophane, cloth, paper, cardboard, porcelain, metal, mica, stone, leather, wood, and plastic sheets and film. Available as greases for the compounding of adhesives, or as solutions sold under the trade-mark "VINYLSEAL." The latter are especially recommended for bonding impervious materials, such as metals, and the urea and phenolic plastics. Their bonding strength is comparable to that obtained with soft solder.

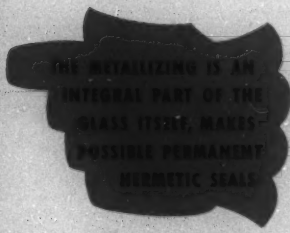
CORNING GLASS RESEARCH ANNOUNCES NEW

HERMETIC



1. Radio Apparatus Bushings. 2. Ring Insulator. 3. Coil Forms. 4. Envelopes for Condensers and Power Resistors. 5. Small Envelopes for Condensers and Resistors.

METALLIZING ON GLASS!



HERE'S an easy solution to difficult assembly problems on units which must be sealed against leakage of air, oil or water. Corning's metallizing method is a big step forward in the art of applying metal to glass. Metallizing becomes part of the glass itself . . . the answer to your hermetic sealing problems. The metallized layer solders easily and is not harmed by normal soldering temperatures. Parts can be soldered to it by ordinary soldering iron, soft air-gas flame or induction heating. And it is tinned to prevent corrosion of the metal during storage and to make soldering easy.

Best of all, Corning type metallizing can now be applied to an extremely wide range of Corning's high and low expansion glasses. Where extreme resistance to thermal or mechanical shock is required, it can be applied to strengthened glass. Where electrical characteristics are of prime importance, it can be applied to some of the special low-loss glasses such as Corning's "Pyrex" Multiform Glass No. 790.

A few of the interesting applications where metallized glass has already been used to real advantage are shown on the opposite page. If you, too, have the job of insulating current-carrying leads or terminals on hermetically-sealed apparatus, do this now: Fill out and mail coupon today for full details on the improved metallizing method developed by Corning Glass Research!

MAIL COUPON TODAY FOR COMPLETE DETAILS!

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Insulation Division, Dept.,N-87,
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Please send me full details of improved method of metallizing on glass.

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Pyrex Insulators

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CONSTANT PIONEERING . . . the unceasing search beyond present horizons for a Better Way . . . this is the responsibility of Leadership.

As man reaches for the stars, through the science of electricity . . . the miracles of Radio and Television . . . the amazing new world of Electronics, we at American Lava Corporation have paced each new achievement with insulation engineered to the new requirements.

When war came upon us with its demands for tremendously expanded production . . . its requirements for higher performance in Communications . . . we were ready with the KNOW HOW gained from 40 years' experience in pioneering, developing and perfecting steatite ceramic insulation.

Our research and engineering staffs will gladly cooperate on today's blue print . . . tomorrow's production.

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CHATTANOOGA, TENNESSEE

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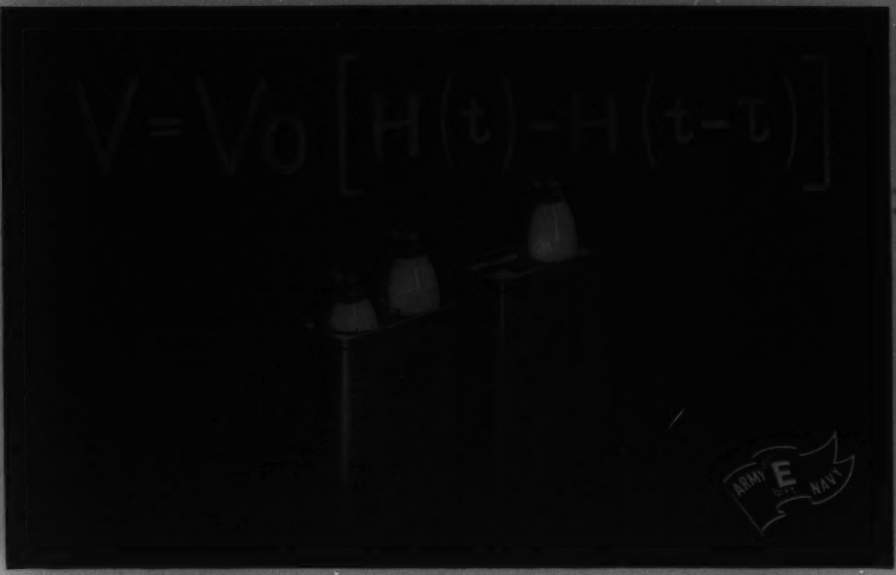
Where stability is an important requirement, ALSIMAG Steatite ceramics are unsurpassed for lending rigidity and permanence of alignment to electronic circuits.

ALSIMAG

STEATITE CERAMIC INSULATORS

CHARACTERISTICS TAILORED TO YOUR REQUIREMENTS



...AND V_o IS ANYTHING UPWARDS OF 1 Kv.!

If you're dealing with voltages of a type indicated by the above formula—well, we don't have to tell you that the job of finding suitable components is a tough one, especially if these V's are working into low Z's.

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On the other hand, more often than not, eminently suitable components have been forthcoming. A typical illustration is the Sprague Type PX-25 "VITAMIN Q" Paper Capacitor that reads "off scale" on megohm bridges at more than 200,000 megohms.

Let us know just what your problems are, and how the capacitors are to be used. We'll make our recommendations accordingly—telling you frankly and honestly just what you can expect.

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NORTH ADAMS, MASS.

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Sprague Specialties Company will be glad to hear from reliable firms having screw machine and metal stamping facilities available for sub-contract work on high-priority orders; also from concerns equipped to make up jigs and fixtures, and having female help available.

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Telephone: NORTH ADAMS (MASS.) 904

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Remote Control BENCH BOARDS

Fabricated by Kirk & Blum for one of the large power companies serving the industrial middle-west.

Accuracy in construction was of paramount importance in this work to permit interchange of panels.

Kirk & Blum's established record of fabricating sheet steel to meet customer's exact requirements and ability to deliver the job when promised, has won for them the patronage of many national manufacturers.

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ACCURATE SHEET STEEL FABRICATION—CAPACITY 3/8 INCH and LIGHTER

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WITH A

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Increased production and time are, perhaps, two of the most important factors in our nation's war effort. That's why a TONG TEST AMMETER should be standard equipment in every plant doing any kind of war work.

This remarkable, portable instrument saves valuable hours because it measures both A. C. and D. C. up to 800 amperes in less than five seconds without necessitating a break in circuit or insulation. This almost unbelievable speed enables maintenance men to keep a closer check on current loads and, thus, keep productive machinery working at top speed.

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COLUMBIA ELECTRIC MFG. CO.
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DESIGNED FOR SPECIFIC APPLICATIONS

U. S. NAVY OFFICIAL PHOTO

The bulk of U.T.C. production is on special units constructed to precise customers' requ[illegible] naturally impossible to describe all of these [illegible] as they become available. Many of them[illegible]

In most cases, toda[illegible] the conservation of material, or provi[illegible] materials. All in all, it is significant th[illegible] jobs find their way to U.T.C.

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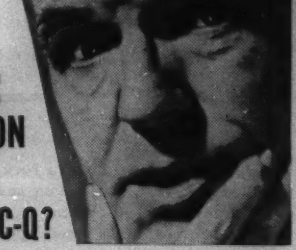

Universal C.Q. is the automatic, controlled quality manufacturing method and skill in producing dry process porcelain of uniform high quality. Product designers and manufacturers are re-discovering the many important and practical reasons why Universal C.Q. is often a better replacement for metal parts than the actual metal part itself. It is *NOT* a critical material; it *has* high dielectric strength; non-corrosive; resists acids; withstands thermal shock and arcing; contains no organic binders; will not carbonize. In addition it can be "finished" to add eye appeal to your product. If you're trying to redesign your product for postwar as well as wartime manufacturing — better get in touch with Universal.

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If you desire to save time and critical materials on production of metal stampings or other small parts, then the DI-ACRO System of "Metal Duplicating Without Dies" merits your consideration. It is based on the rapid and accurate production of formed parts with DI-ACRO Shears, Brakes and Benders. All duplicated work is accurate to .001". These precision machines are adaptable to an endless variety of work, and ideally suited for use by girl operators. For short runs your parts are processed in a matter of hours instead of waiting weeks for dies.

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One piece Drawn Steel Transformer Case without seams or joints is, because of its simplicity, the strongest type of mechanical construction. Then, too, the one-piece construction provides an unimpeded electrical and magnetic path resulting in better shielding from outside electrical disturbances. Absence of seams also assures maximum protection against atmospheric conditions—guarantees longer transformer life.

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Pioneers of the Compound Filled Drawn Steel Transformer Case

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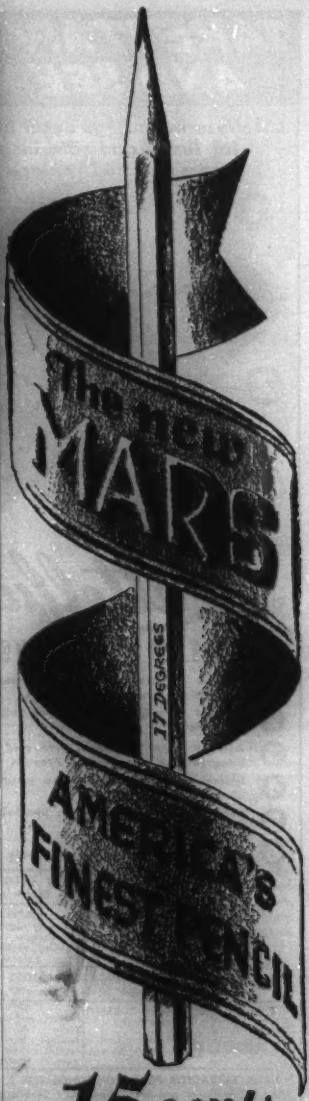

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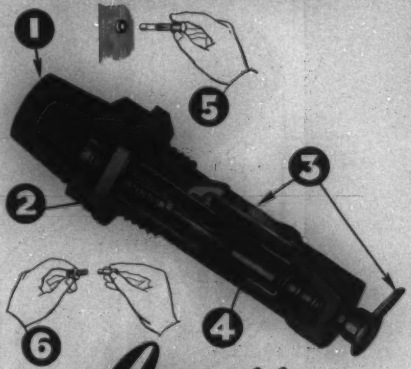

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1. **Molded of black bakelite—thoroughly insulated preventing corrosion and shorts.**
2. ***Positive Fuse Grip* permits full visual shock-proof inspection.**
3. ***Anti-vibration Terminals.* Side and end terminals integral with metal parts. Prevent vibration.**
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5. ***Knob pulls and holds Fuse.* Special grip prevents fuse from dropping out.**
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AIRCRAFT MOUNTINGS FOR 4 AG FUSES
Screwdriver and finger operated. Length overall 2½".

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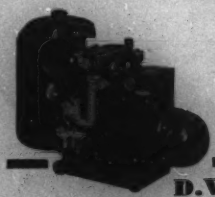
Thousands of these reliable, sturdy plants are doing a winning job on all the fighting fronts by providing power and light for many vital war tasks.

Ratings from 350 to 35,000 watts. A.C. 50 to 800 cycles, 110 to 660 volts. D.C. 6 to 4000 volts. Also dual A.C. and D.C. output models. Air or water cooled engines.



Details gladly furnished on your present or post-war need for Electric Plants.

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Perfect INSULATING COMPOUNDS
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In the Northern States, on the Gulf Coast, and both east and west—Minerallac Insulating Compounds are specified . . . proving that these materials do "stand up" no matter what change in temperature may arise.

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MINERALLAC ELECTRIC CO.
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OHMITE Rheostats

For Control of Motor Speed and Generator Fields
For Control of Electronic Tubes
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Widest Range of Sizes for Every Rheostat Need

Today's critical service requirements further emphasize the basically sound design of Ohmite Rheostats. Their many time-proved features provide *permanently* smooth, close control in countless applications.

There are ten wattage sizes ranging from 25 to 1000 watts—from 1 9/16" diam. to 12" diam.—in straight or tapered winding—in single or tandem units—in regular or special designs to provide the exact unit for each application. Units produced to Government specifications. Ohmite engineers are glad to assist you on any rheostat problem.

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★ Reliable
★ Made in U. S. A.

. . . the JONES heavy duty HAND TACHOMETER

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We suggest the Jones Heavy Duty Hand Tachometer for indicating rpm and surface speeds of all types of machinery in which the moving parts are readily accessible.* It is built to "stand the gaff" and maintain accuracy in hard, everyday service. Single and triple range models up to 12,000 rpm. Instruments are furnished complete with carrying case, including extra tips. Rubber-tired wheel for measuring surface speeds available at slight additional cost.

Write for new descriptive Bulletin 1710-EE

*Where moving parts are not readily accessible, as in turbines, centrifugal pumps and other totally enclosed machines, and also for measuring vibrations per minute, we recommend our Frahm Vibrating-Reed Tachometers. Ask for Bulletin 1590-EE

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Engineering assistance by consultation or correspondence is freely offered in solution of your magnetic design problems. All inquiries will receive prompt attention.

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TWO IMPORTANT, PERMANENT ENGINEERING POSITIONS ARE OPEN

Connecticut Telephone & Electric Division of Great American Industries, Inc. needs two experienced men in its Meriden, Connecticut plant.

The first man should have a thorough knowledge of acoustics and experience with magnetic circuits and acoustical measurements.

The other man must be familiar with the application and molding technique of plastics. He should have several years of design experience on small electrical apparatus, and an understanding of magnetic and electrical circuits.

"Connecticut Telephone" is a prime war contractor with an assured peacetime future. The two engineers described above will work on both wartime and postwar projects. Write, phone or wire Mr. William R. Curtiss, Chief Engineer, Connecticut Telephone & Electric Division, Great American Industries, Inc., Meriden, Connecticut.

Men now employed at their highest skill in war industry need not apply.

GREAT AMERICAN INDUSTRIES, INC.

70 Britannia Street
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PROTECTION *for Electrical Equipment* WITH THE HYPOT

Prevent serious delay and breakdown in electrical equipment . . . test for insulation quality with the HYPOT! In quick time you can locate and repair insulation faults that would burn out in operation. The HYPOT has ample capacity for all testing . . . quick easy control from zero to maximum voltage . . . exclusive "Burn and Test" feature . . . meets all AIEE specifications . . . self-contained, sturdy, compact, portable . . . complete safety to operator and equipment. Write today for full information.

ASSOCIATED RESEARCH

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Small, compact and lightweight

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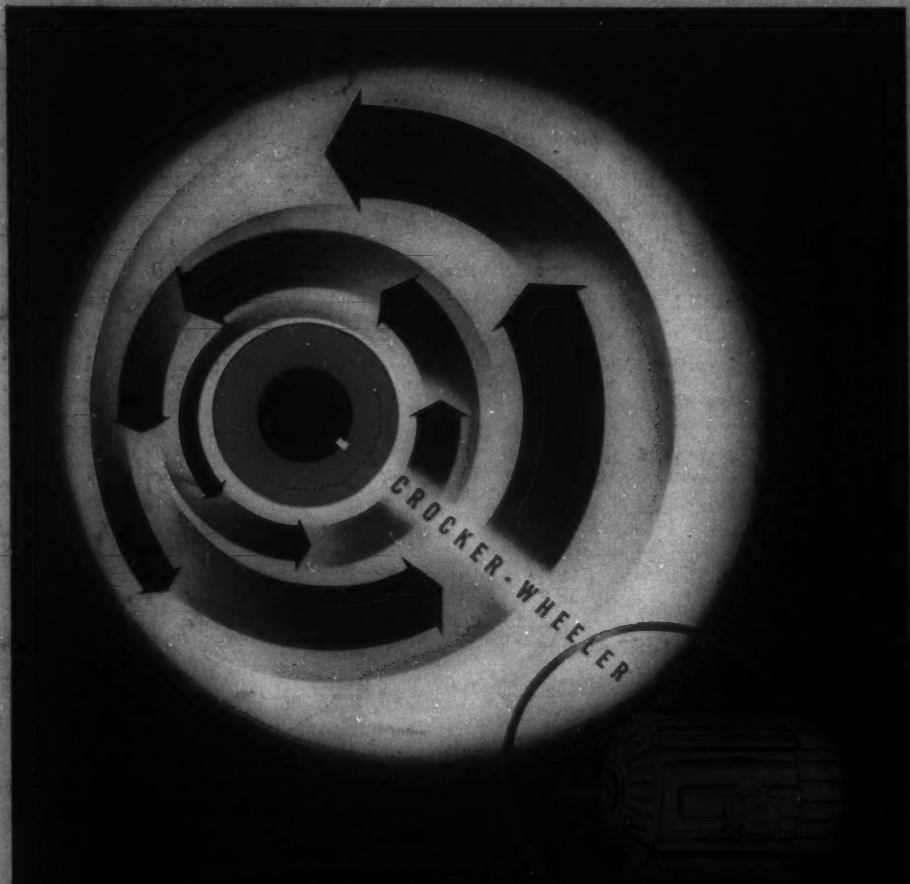

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